# The American Journal of Surgery

EDITED BY THURSTON SCOTT WELTON, M.D.

February 1942

## TRAUMATIC SURGERY

Papers Read at the May 1941
Meeting of The American Association
for the Surgery of Trauma

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WALTER HERMAN RYFF in his *Great Surgery*, published in 1546, describes a number of mechanical methods for closing wounds. Among them was the device of applying strips of plaster to the wound edges and sewing through the fabric instead of the tissues. Another described as a small clasp with a barb at each end is perhaps a forerunner of the skin clip. Ryff came from Strassburg originally, but spent his last twenty years in Mainz and Nurnberg. He was a prolific writer credited with the authorship of 48 books.

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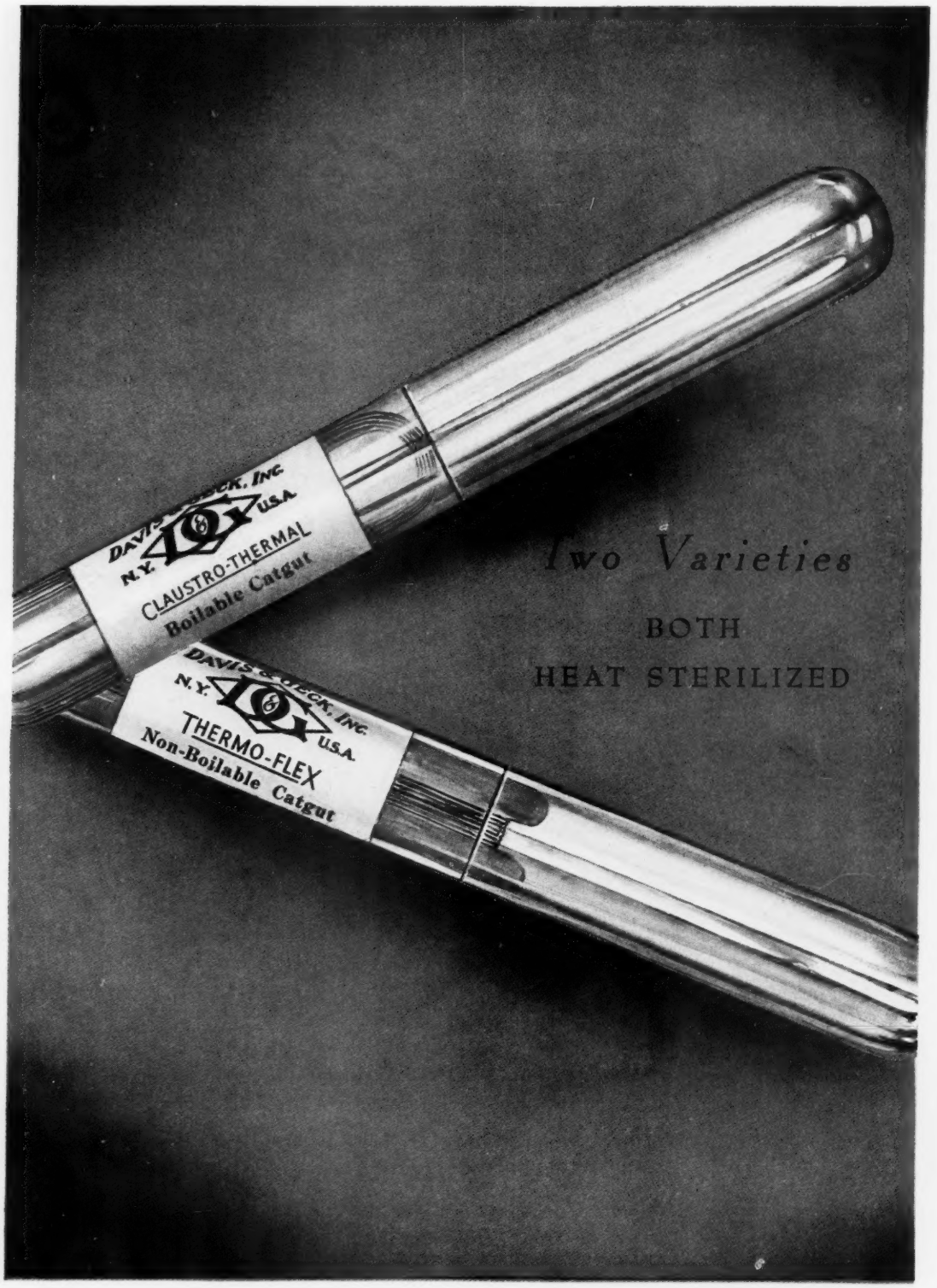


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How small the suture should be is determined by its ability to improve the character of wound healing. To do this, the suture may be gossamer, or at least exceedingly fine. The clean wound sutured with the smallest amount of material capable of adequately maintaining continuity has the least extensive and shortest exudative reaction. Uninjured cells begin to proliferate and the wound begins to gather strength in the shortest length of time after repair.

On the other hand, increasing the amount of suture material, particularly by using a larger size, increases the exudative reaction, provides a better foothold for bacterial growth, correspondingly delays cellular proliferation, and the wound remains weak for a longer period of time.

How large the suture should be is related to its strength and the number of sutures employed. The suture must have sufficient strength to satisfy the mechanics of insertion and tying the knot. This, however, becomes secondary if the mechanics are satisfied by the use of large sizes temporarily to relieve tension while the finer ones are being placed.

The immediate strength of the sutured wound is largely determined by the capacity of tissues to hold sutures. The strength of the wound can always be made adequate by employing enough sutures. Regardless of how fine they may be, each suture adds strength to the suture line and the capacity of the tissues to hold sutures becomes greater when the load is distributed.

The first principle underlying the selection of the suture is that it must be small enough not to interfere with early proliferation of cells after repair of the wound.

The second basic principle is that the mechanics of suturing can be satisfied and the wound given adequate strength if a sufficient number of sutures of fine size are employed.

*Discussions of nine subjects in this series on Suture Use have been published. Reprints (including the above) and a bibliography will be sent on request.*
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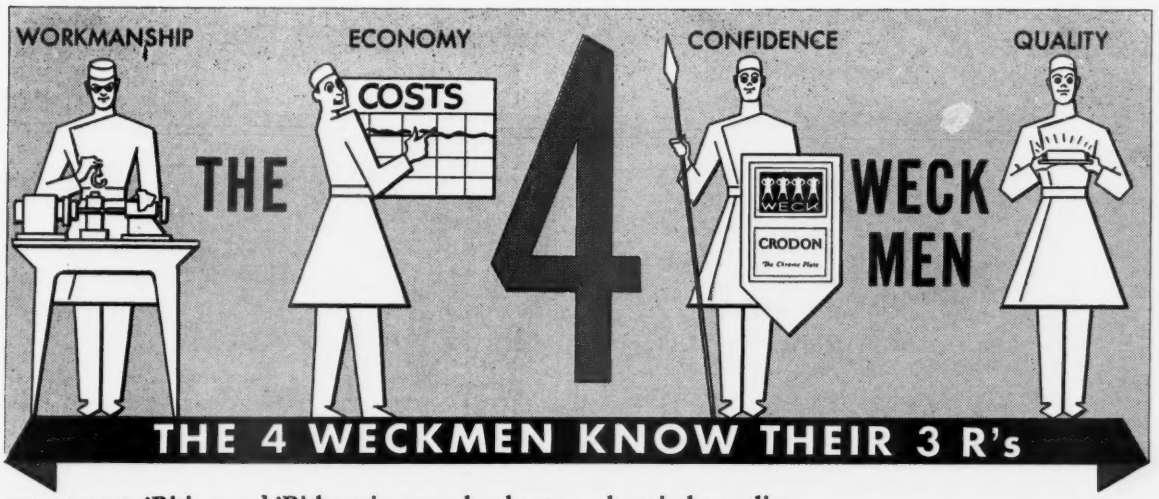


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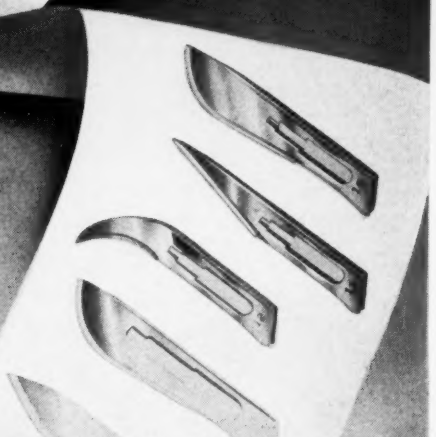

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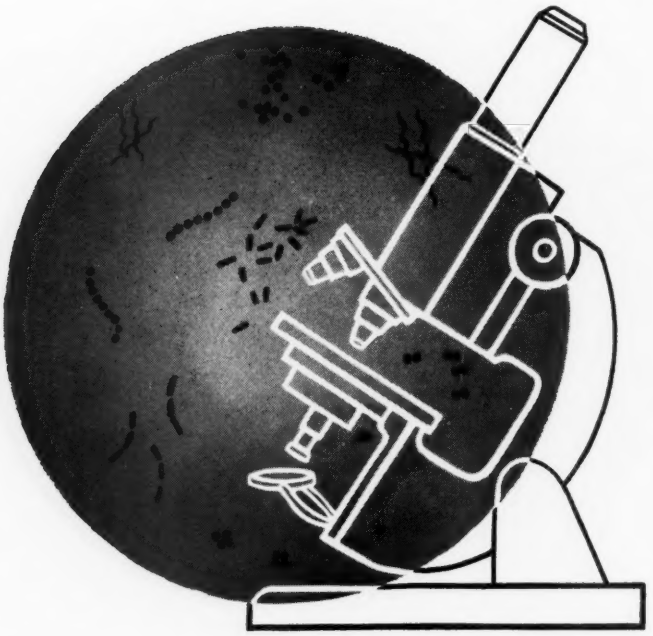

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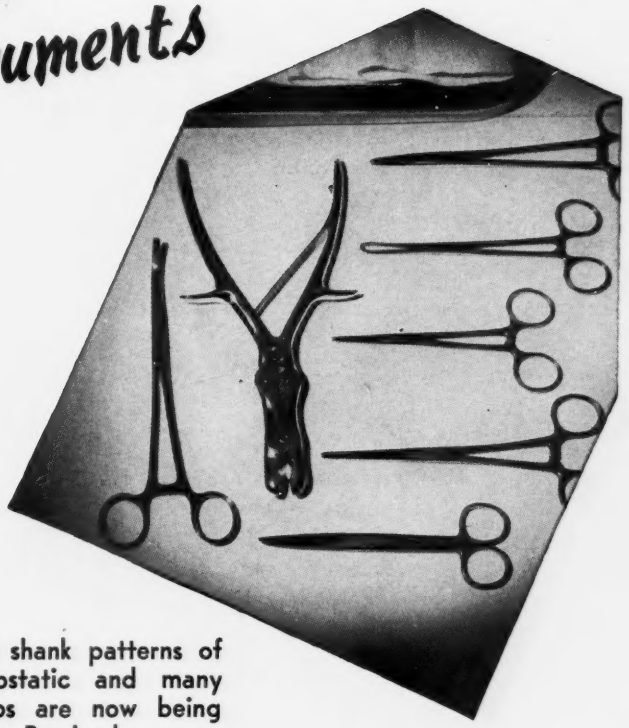

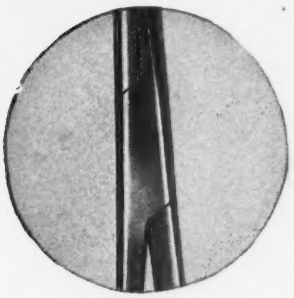

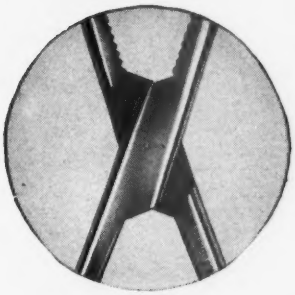

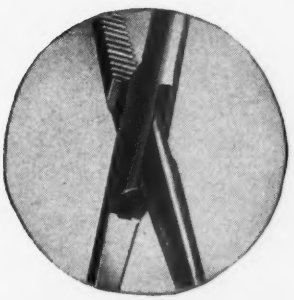

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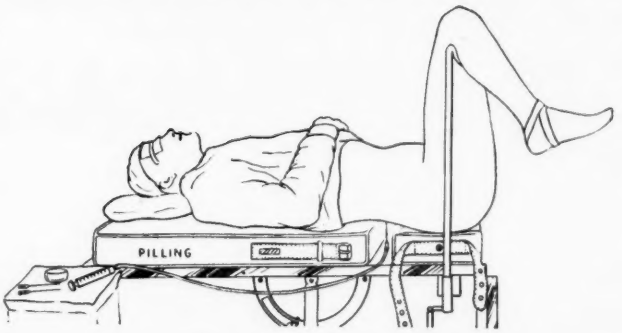


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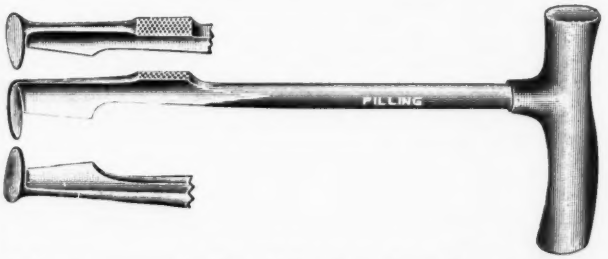


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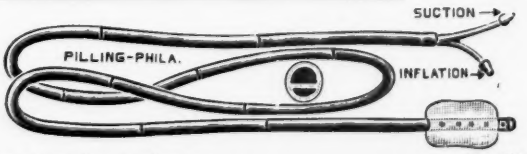


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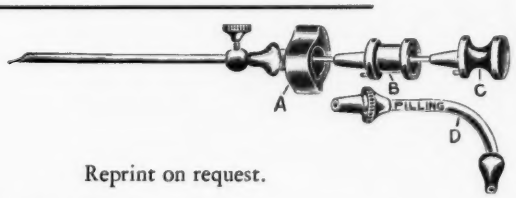


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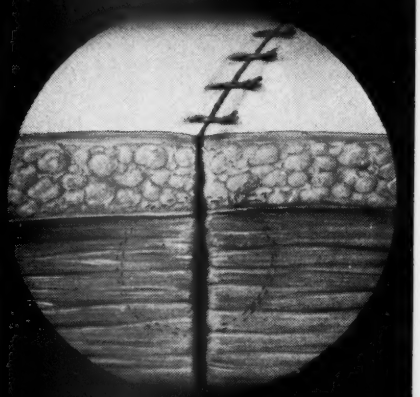

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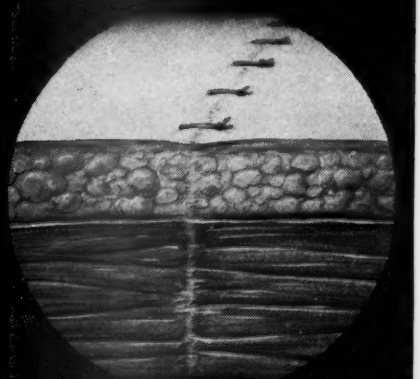

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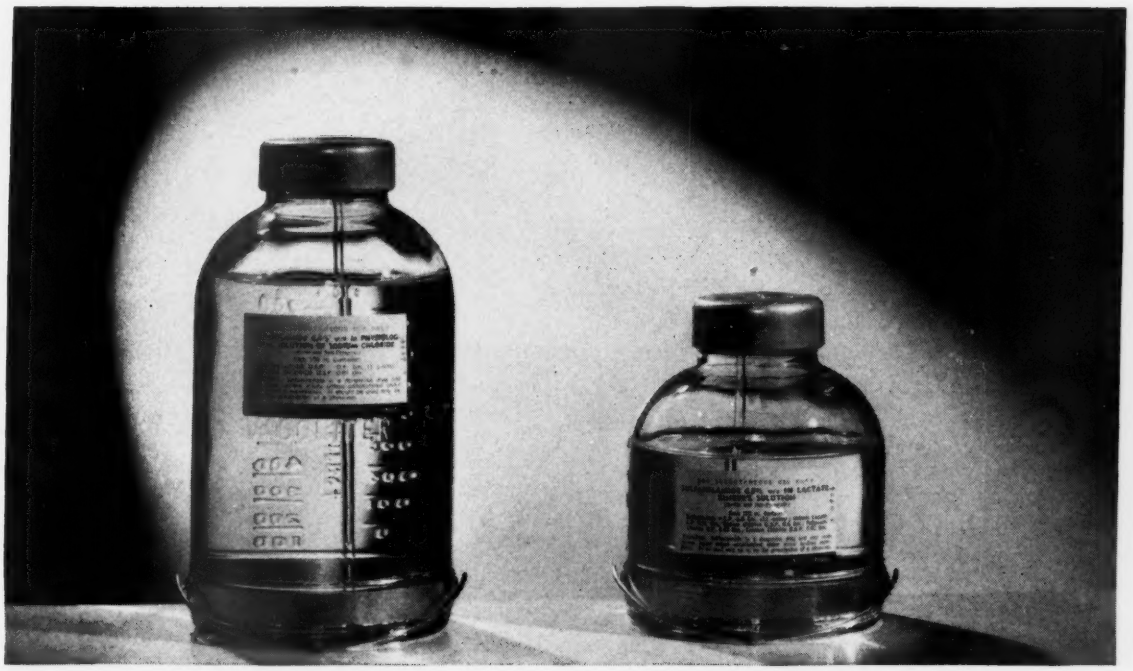

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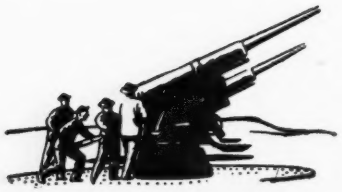

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NEW SERIES VOL. LV FEBRUARY, 1942 NUMBER TWO

# Editorial

## THE TREATMENT OF GUNSHOT WOUNDS*

PRESIDENTIAL ADDRESS†

FRASER B. GURD, M.D.

MONTREAL, QUEBEC

TO discuss the subject of gunshot wounds properly, a volume of not inconsiderable proportions would be required. I believe, however, that it is possible to discuss wounds due to projectiles, as such, without specific reference to involvement of individual structures, such as the brain, lungs, heart, abdominal viscera and joints, since there are certain general principles which are applicable to the treatment of most, if not all, wounds of this sort. In order that my contribution may be kept within reasonable bounds the subject of burns shall not be discussed; nor shall the treatment of shock be considered. The two very interesting new phenomena of *blast* and *crush* cannot be discussed.

My justification for attempting to address you on this subject is based upon a prolonged experience during the first stage of the War. Commencing in June, 1915, I cared for wounded soldiers during a ten-year period. Of this time thirty months were spent at a Casualty Clearing Station, four months with Sir Robert Jones at Alder Hey, Liverpool, four months at a Base hospital in France and several years in charge of surgery at Ste. Anne's Military Hospital in Canada.

* From The Montreal General Hospital, McGill University.

† Presented before the Annual Meeting of the American Association for the Surgery of Trauma, Seigniory Club, Montreal, Quebec, May 30, 1941.

Since 1925, I have maintained my interest in wound protection and treatment and together with my colleague, Dr. L. H. McKim, have carried out intensive studies of the various technics which have from time to time been recommended. Every opportunity has been given to other members of my staff and to succeeding residents to treat wounds as seemed good to them, subject only to reasonable oversight. Since September 1939, both Dr. McKim and I have made every effort to keep in touch with such publications and memoranda as have become available particularly in the English literature. We have had, too, the very great pleasure of conferring with Dr. Philip Wilson whom the Association is so delighted to welcome as a guest at this meeting and from whom we hope to hear much of interest.

Most or all of the fellows know of the enthusiasm already expressed on more than one occasion by both Dr. McKim and myself with reference to the employment of B.I.P.P. and liquid paraffin;[1,2] if in this contribution comparatively little is said about this technic, I do not wish it to be understood that our views in this matter have undergone any modification.

As compared with what Bernard Shaw has called the Four Years' War, the present conflict has been comparatively trivial in so far as both the number of wounded and the nature of wounds are concerned. Up to May 23, 1941 figures relative to British losses in all fighting services and among civilians have been less than 175,000 persons including killed, wounded and prisoners. It is evident that the problem of the treatment of war wounds has still to be met by the medical services. Hitherto, as was the case in the Spanish war, the comparative ease with which the wounded have been handled, the early opportunity offered for careful mechanical treatment and the usual lack of necessity for rapid evacuation have made it possible for good results to be obtained without the exhibition of ancillary methods. These facts should not, however, lead us to the wishful conclusion that wounds such as we knew them during 1914 to 1918 will not be met with at a later date.

One of the major difficulties in speaking of war wounds is that the conditions under which they are suffered by the various members of the army, navy and air forces in this war as compared with those in the last war by civilians, vary so enormously. The variations depend, *inter alia*, upon the time of the year, the nature of the country particularly with reference to the character of the soil and the extent to which it has been cultivated, the character of the

military operations and the nature of the projectile inflicting the wound.

### FACTORS WHICH INFLUENCE THE NATURE OF WOUNDS AND TYPE OF TREATMENT INDICATED

*Micro-organisms and Gas Gangrene.* Although in France and Flanders, particularly during the earlier years of the first stage of the war, practically all wounds were contaminated with the micro-organisms responsible for gas gangrene, this had not been the case in the South African War. During the war in Spain, too, this nightmare of the surgeon in France was largely absent. In so far as the British campaigns were concerned, during the first phase, the Mesopotamian force did not meet with this type of infection and in Gallipoli the incidence was relatively small. Hitherto, fortunately, in this war massive gas gangrene has not been prevalent.

*Effect of Season upon Wounds and Wounded.* In the summer the soil is relatively dry; the soldiers' clothing is relatively clean; shock accentuation due to chilling is minimal, and the roads are hard permitting rapid evacuation. During the winter the soil has turned to mud or slush; the soldiers' clothing is filthy; the lowering of body temperature deepens shock, and the roads are unfitted for rapid evacuation.

*Character of Soil Affects Wounds.* Dry sandy soil is free from infection and a delay in operating is not serious. Primary suture is indicated in such instances. Wet, highly fertilized soil teems with bacteria especially anaerobes: Clostridium and welchii œdematis maligni, Bacillus tetani and streptococci. A delay in operating is dangerous in the extreme and a primary suture is rarely indicated. A secondary suture is possible if the primary wound treatment has been adequate.

McNee and Dunn, in a series of twenty-five consecutive cases admitted to Casualty Clearing Station in the first British Army in France, and less than twenty-four hours old, found Bacillus aerogenes capsulatus in twenty-three cases and streptococci in nine. A. Fleming, in 1915, found Bacillus aerogenes capsulatus in 103 of 127 wounds of patients evacuated to England from France. These wounds were one to seven days old. In 102 cases streptococci were present.

Even in France and Flanders where, as indicated above, contamination with anaerobic bacteria was extremely widespread so that practically all wounds became more or less infected with the

Clostridium welchii, the bacillus of malignant edema and both aerobic and anaerobic streptococci, the incidence and gravity of these infections was much lower in the summer time than in the winter. This was due in all probability to the fact that in the winter time the soldiers' clothing was certain to be filthily contaminated with mud from the highly fertilized soil.

### CHARACTER OF MILITARY OPERATIONS AFFECTS WOUND TREATMENT

The character of the military operations is of importance for several different reasons: In the first place, under what were spoken of during 1914 to 1918 as peace or quiet times in trench warfare most of the wounds were inflicted by hand grenades or trench mortars. Wounds by hand grenades were often comparatively trivial and the amount of tissue laceration due to such wounds was minimal, although frequently multiple. Wounds due to trench mortar projectiles were usually fatal at once since the high explosive charge carried by these bombs resulted in great destruction in their immediate neighborhood although, as the result of the irregular contour of the trenches, the neighbourhood affected by their activity was minimal. A comparable observation has been made by Broster[3] among air raid victims in Britain. Although the number of killed is almost equal to the number wounded, the majority of wounds, he states, are comparatively minor.

### CLASSIFICATION OF WAR WOUNDS BASED UPON THE NATURE OF PROJECTILE

*Rifle and Machine Gun Bullets.* Their velocity is high; a small entrance is made and often a small exit unless the bullet is ricochet. These bullets perforate clothing and skin but often do not carry in any of the clothing. Heat may sterilize the wound which is favorable; centrifugal force causes necrosis of the cylinder of tissue and this is unfavorable. If reasonably early, such wounds may often be excised *en masse*, "bipped" and a primary suture employed. If a bone has been hit, a large exit wound and severe comminution result.

Although but few cases have been reported, Ross and Hulbert describe the care of a pilot officer who had his left humeral head shattered by a tracer bullet; the wound was still smoking when it was excised.

*High Explosive Shell or Bomb (Aeroplane) Fragments and Trench Mortar Bombs.* These cause severe mutilation and many complica-

tions; clothing and skin are carried into the depths of the wound and marked contusion and consequent devitalization of tissues occur. These shells are relatively slow moving and have little tendency to puncture but rather tear way into tissues. There is a wide variation in size and speed (momentum) of these projectiles; wounds differ much in character and extent.

*Collapse of Dugouts, Houses, Shelters, etc.* Serious injuries to head, spine, thorax and pelvis are common but often no open wounds are caused.

*Shrapnel Balls.* These are slow moving, blunt and are more likely to puncture than shell fragments or rifle or machine-gun bullets; they have a marked tendency to bounce.

*Hand Grenades—Mills Bombs.* The fragments are small and relatively slow moving (momentum low); they cause deep penetration not marked, but multiple wounds are common. Early removal is recommended and often primary suture with B.I.P.P.

When active military operations are in progress, it is more important that reinforcements and supplies get up to the fighting troops than that casualties be evacuated. Roads subjected as they are to artillery fire and bombing are necessarily employed for combatant purposes and delay in reception of wounded is inevitable.

When wounded are arriving at Casualty Clearing Station by the thousands in a few hours' time, evacuation to base must be accomplished as rapidly as transport is provided. All surgical intervention must, therefore, be of a nature that will absorb little time and the technic must render the wounded soldier as safe and comfortable as possible if many hours or days must elapse before further operating room treatment is available.

During battles, as for instance the battles of Vimy Ridge, Messines Ridge and Paschendaele, regarding which my knowledge is most intimate, the number of soldiers severely wounded who presented themselves for treatment at the Casualty Clearing stations made it absolutely impossible for the individual wounded to receive the necessary surgical intervention within a reasonable lapse of time.

### PERSONNEL AND EQUIPMENT OF SURGICAL TEAM IN BRITISH CASUALTY CLEARING STATIONS—1916 TO 1918

The personnel and equipment consisted of one surgeon, one anesthetist, one nursing sister, one o.r. corporal, one batman; one operating table, two complete sets of instruments, and a complete assortment of linen dressings and traction splints.

Although at our Casualty Clearing station we had received two reinforcing teams, making four teams in all, the situation created during the first twenty-four hours and longer of the battle of Vimy Ridge made it absolutely impossible to carry out adequate surgery. During the first twenty-four hours of this battle we received over three thousand stretcher cases and a larger number of ambulatory patients, the exact number of which we never checked up owing to our inability to supply clerks even to take their names. Of the three thousand or more stretcher patients at least two thousand deserved and required immediate surgical intervention. Enough has been said to indicate that this was impossible. As a matter of fact, during this battle within an hour after we commenced to receive the wounded we were forced to the decision that no head injuries would receive any attention. Within another hour the same decision was arrived at with regard to chest injuries and before three hours had elapsed it was decided that no patients with abdominal injuries would be operated upon. The soldiers, therefore, suffering from these three types of wounds were placed in marquees under the care of a single orderly whose only armamentarium was water and morphine.

Since the battle of Vimy Ridge commenced at daybreak in April, 1917, after a night of snow and sleet and with a temperature close to 32°F., all wounded were soaked with mud slush. Practically all stretcher cases were pale and pulseless and proved to have a body temperature too low to record on a clinical thermometer. Most had been wounded eight hours or a longer period prior to admission and, although they had received hot fluids, all were dehydrated and it was necessary to employ incandescent heaters and administer intravenous blood and glucose solutions before operation could be undertaken.

Later in the same year (1917) my team had the good fortune to work in the Second (British) Army during the battle of Messines Ridge with the First Australian Casualty Clearing station. During the first twenty-four hours of the battle we received two thousand wounded but owing to the fact that fourteen teams had been made available nearly 1,100 patients were operated upon in the one twenty-four-hour period. This was made possible by a method of classification which made it unnecessary for ten of the operating surgeons to see cases prior to operation and also because each surgeon working in this setup had two anesthetists and three operating tables. The number of wounded as compared with the number of

surgeons and adequacy of equipment, therefore, influences the delay which may occur after admission of the wounded.

Further examples of the necessity for all speed compatible with safety of life or limb could be given, but sufficient, however, has been said to indicate that military operations have a profound influence upon the nature of the surgery possible.

Under normal conditions in our civilian hospitals three aims are of paramount importance: (1) To save the life of the patient; (2) to discharge the patient with as little impairment of normal function as possible; (3) to obtain aims (1) and (2) with as short a loss of time to the patient, and with as little expense as possible due to stay in hospital.

Under battle conditions, when the number of surgeons and surgical teams available under the most favorable conditions is bound to be inadequate, there must be added to the above three desiderata an even more important item, namely, the adoption of a technic which will permit adequate treatment of as large a number of wounded soldiers as is possible in the shortest possible time.

As Sir Anthony Bowlby[4] said early in 1918, "If more primary sutures are to be carried out there must be more strong stretcher bearers and more surgeons." He also said, "If primary suture is to be employed rest for at least seven days without evacuation must be available." He placed himself on record as being an advocate of both B.I.P.P. and flavine.

As a preliminary to a consideration of a few of the proved methods of treating wounds it is, I believe, in order to make certain general remarks regarding both the operative procedures and the supplemental or ancillary methods to be employed following operation.

Operative procedures may be listed as follows: Radical incision of skin, subcutaneous tissue and fascia so as to permit: (*A*) Removal of foreign bodies: projectile, clothing, mud and gravel; (*B*) excision of devitalized and contaminated tissue (débridement); (*C*) careful exploration of all deep interstices, and (*D*) fixation to provide rest: traction, plaster of Paris.

It need not be urged here that the earlier operative interference is accomplished following injury the better the results are likely to be and the larger the proportion of primary sutures made possible. Enough has already been said to indicate that under battle conditions reasonably early operative interference is, as a rule, an impossibility. It may, however, be stated in general terms that operative

interference is carried out on the one hand in order to remove foreign bodies, projectiles, clothing, mud and gravel, or as in the case of air raid injuries, wood fragments of masonry and other portions of dwellings, and other buildings, and on the other hand to permit excision of devitalized and contaminated tissue which is likely to act as a culture medium from which bacteria, gangrene producing and other, are likely to invade the surrounding tissue.

Furthermore, at the completion of operative interference and the institution of whatever ancillary method is deemed advisable, the establishment of some method for adequate fixation is imperative. During the war of 1914 to 1918, the various methods of traction with the employment of Thomas splints and modifications thereof were most generally employed. It is possible, nay probable, that in the present war the application of plaster of Paris will be the more usual method of providing fixation particularly in so far as air raid wounds are concerned and those caused between battles. In this connection the importance of Trueta's observations in Spain cannot be minimized.

Although surgeons in many parts of the world were of the opinion in 1914 that they knew a good deal about the treatment of wounds, it soon became evident in France and Flanders that practically nothing was known about the handling of severe wounds due to the impact upon, and penetration of the tissues by projectiles. In most war wounds the lacerations are invariably complicated by an area of widespread contusion. In France and Flanders, moreover, practically all wounds were filthily contaminated with soil heavily loaded with excreta from both animals and man.

Up to the end of the Summer of 1915, the method of treating wounds was primitive on the one hand and disastrous on the other, and consisted for the most part in either no, or very inadequate, incision and the introduction of either rubber drainage tubes or a paste containing antiseptics. These antiseptics were forced into the deeper tissues through the wound made by the projectile. This procedure, as may well be realized, resulted in blocking of the wound so that secretions could not get out and in establishing the most perfect anaerobic conditions possible.

Gradually, on the part of all surgeons working at Casualty Clearing stations, disatisfaction with either of the above methods of treatment became evident, and in all Clearing stations one noted the more radical incision and then the excision of wounds. By the Spring of 1916 this more radical treatment had become generally used and

eusol (Edinburgh University solution) was being employed for lavage and the packing of wounds which had been incised and, in part, excised. In some cases in which anatomically it was possible to excise the track of the bullet completely this procedure was adopted, and in some of these cases primary suture was employed and was sometimes successful.

After adequate operative procedures have been carried out, in the great majority of battle wounds, most surgeons will feel the urge to supplement their operative interference by one or more of the ancillary procedures available.

A classification of supplemental methods of treatment of contaminated and infected wounds following operative procedures may be made under the following four headings: (1) The employment of antiseptics or germicides; (2) the employment of hydroscopic substances to stimulate lymphorrhea; (3) the employment of curtain drainage, and (4) the employment of agents capable of destroying necrotic tissue.

### ANTISEPTICS OR GERMICIDES IN WOUND TREATMENT

Of the substances coming under the above heading which have been more generally employed and which have proved their usefulness under war conditions are: (1) Eusol and Dakin's solution—chlorine; (2) acriflavine, brilliant green and gentian violet—analine dye products; (3) alcohol, alcoholic iodine solution, ether; (4) iodoform and bismuth subnitrate; (5) sulfonamide group, and (6) potassium permanganate.

Although there is much evidence to support the thesis that the analine dyes mentioned are safe in proper dilutions and possess definite germicidal properties, time does not permit an adequate consideration of their merits. It must suffice for our purposes to quote from an article published early in 1918 by Pilcher and Hull:[5]

"For ease of preparation and application, rapidity when dealing with large numbers of cases, complete absence of surgical fidget, early cleaning of the wounds and abatement of constitutional reaction to absorption, flavine 1–1000 (and its cogener brilliant green) is an admirable application under all circumstances and especially when surgeons are few, time is short and wounds are many."

### HYDROSCOPIC SUBSTANCES TO STIMULATE LYMPHORRHEA

There is much evidence to support the contention of Sir Almroth Wright that a tendency towards sterilization of wounds and a

stimulus to healing may be brought about by the technic which he has referred to as the "physiological method" of wound treatment. The essential feature of this technic is the application to the wound surface of substances which possess the property of stimulating discharge of tissue fluids and, also, interference with deposition of fibrine on the surface which to use Wright's expression, results in "lymphatic block." Wright, many years ago, introduced a hypertonic sodium chloride solution plus sodium citrate for this purpose.

Early during the war of 1914 to 1918, Colonel Gray introduced the salt pack. Further reference will be made to this technic in discussing the Reading bacillus.

The most active hydroscopic agent that I have employed is that of magnesium sulfate cream in glycerine as introduced by A. E. Morrison.

The general statement may be made regarding the hygroscopic agents that the possibility of extreme dehydration must be borne in mind and their use avoided over too large surfaces.

### TECHNICS WHICH PERMIT AND INDUCE CURTAIN DRAINAGE

In order that our consideration of wound treatment may be complete it is necessary, I believe, to refer at least to the subject which may best be classified under the heading of agents which destroy necrotic material in the wound. Under battle conditions the urgency of safe though often inadequate operative treatment becomes imperative. The result may be, and often is, the necrosis of tissue *in situ* which has either been destroyed by the original wound or by bacterial activity later. When such a situation is met with the employment of the salt pack may prove life saving to many soldiers.

One major advantage of Gray's salt pack is that dressings need not be changed at an interval of less than from seven to ten days. This permitted evacuation of the wounded by train and boat with comparative safety and avoided the discomfort of frequent dressings. In 1917, J. L. Joyce who was stationed at Reading (Hampshire), noted that among patients treated by the salt pack who arrived at his hospital in the center of England the condition of the wounds could be estimated prior to the removal of dressings by the presence or absence of a foul odor. Rather surprisingly, it was noted in this connection that in those cases in which the odor was foul the condition of the wound was good, whereas in those cases in which the dressings were sweet the results were likely to be unfavorable.

Donaldson, a bacteriologist, examined these wounds and found that there was uniformly present in the cases that were doing well the presence of a spore-bearing proteolytic bacillus. This bacillus they were easily able to isolate in pure culture and gave it the name, Reading bacillus.

A large series of patients were treated by Donaldson and Joyce by means of either the salt pack or a pack composed of sphagnum-moss, the wound having been purposely contaminated with a pure culture of the Reading Bacillus. Their opinion, and there is much to support it, was that the nonpathogenic micro-organism assisted in the digestion of all devitalized tissue or slough in the wound.

In so far as I know, no one has carried out investigations in cases in which the occlusive plaster malodorous method was used as recommended by Orr and Trueta with a view to proving or disproving the presence of this spore-bearing proteolytic, nonpathogenic anaerobe. That this should not have been done is rather surprising.

*Carrel-Dakin Technic.*[7] During 1915 Dakin had introduced a hypochlorite solution comparable to, though more accurately standardized than, the Edinburgh University solution (eusol). Both depended for their usefulness as antiseptics upon the presence of sodium hypochlorite, and both had proved to have both *in vitro* and *in vivo* definite germicidal properties. At the same time, although normal tissues were not damaged, except for the skin, by the continued application of these solutions, both, but more particularly Dakin's solution, had the useful property of bringing about digestion or lysis of necrotic tissue and fibrin.

Late in 1915, Alexis Carrel went to France at the head of an American unit to assist the French in the care of the wounded and, more particularly, to carry out experiments which might lead to an improvement in wound treatment.

Carrel and his staff realized as had practically all Clearing station surgeons by that time that an essential feature of wound treatment must be wide incision and adequate excision of tissue. Furthermore, they introduced a definite and new method of wound treatment which became known by the descriptive expression "discontinuous irrigation with Dakin's solution."

*Essentials of Carrel-Dakin Method. Operative:* The essentials of the Carrel-Dakin operative method are: (1) Adequate incision and excision of devitalized tissue; (2) removal of foreign materials including, projectiles, clothing, and mud and gravel; and (3) fixation by traction.

*Essentials of Carrel-Dakin Method. Discontinuous Irrigation:* The technic of the Carrel-Dakin method of treatment is, I am sure, known to all. The essentials are, first wide incision and sufficient excision of tissue together with the removal of foreign bodies such as shell fragments, bullets, clothing material, and mud and gravel. After the wound has been so prepared that it is possible to examine adequately its deeper parts, small caliber rubber tubes, closed at the end but with multiple small openings close to the end on the sides of the tubes, are introduced into all the interstices of the wound toward the bottom. At hourly intervals Dakin's solution is run through the tubes thus reaching the bottom of the wound, and among other things washing out the wound from below. The action of the solution in addition to its mechanical one is due to its ability to bring about dissolution of dead tissue and fibrin and to the germicidal effect of the chlorine liberated.

*Advantages of Carrel-Dakin Technic.* The advantages are: (1) Adequate incision and removal of foreign bodies and damaged tissue; (2) wound lavage; (3) dissolution of sphacelus; (4) germicidal effect of chlorine, and (5) fixation

If the operative procedure has been adequately carried out, if the tubes have been positioned satisfactorily, and the discontinuous irrigation successfully attended to, there is no doubt that in most wounds substantial sterilization can be obtained so that secondary suture may be employed.

*Disadvantages of Carrel-Dakin Technic.* The main objection, particularly under battle conditions, to Carrel-Dakin's method, a method which received wide publicity and protagonism on this continent due in large measure to the enthusiasm of William O'Neil Sherman's[8] dynamic advocacy, is that the nursing care required for its successful employment is great. Although theoretically it would seem possible to prepare an automatic reservoir which would discharge the proper amount of fluid which would distribute itself into each of the many tubes in the wound, in practice this does not work out. In a case in which six or eight tubes have been introduced it is likely to be found that there is more back pressure on two or more of the tubes than on the remainder, with the result that that part of the wound served by the more or less occluded tubes does not receive its proper quota of solution. Under battle conditions, therefore, it was our invariable experience in France (at a Casualty Clearing station) that this method of treatment broke down and that it became in the individual case a somewhat dangerous trap.

*Curtain Drainage.* This term was introduced by Sir George Makins who was Consultant-in-Surgery in the Base area early in the course of the last war. He, however, did little to advance its usefulness; it remained as an ideal until the introduction of the B.I.P.P. method of treatment by Mr. Rutherford Morison.[9] Although Morison's original method provided but a thin film of liquid paraffin to the surfaces of a wound, it was not long before the supreme importance of the paraffin in the B.I.P.P. was recognized by a number of surgeons working in Clearing stations and in the British Home hospitals. The result was that in addition to the employment of Morison's original technic in order to facilitate and render safe either primary or secondary closure of wounds, it was found to be advisable in many cases of more seriously contaminated wounds to pack them widely open by means of large quantities of gauze soaked in liquid paraffin and to which a limited amount of B.I.P.P. had been added.

*Rutherford Morison's B.I.P.P. Method.* Before the end of 1915 Rutherford Morison stated that "disheartened by the results of treatment employed, I gradually developed a new method of dealing with infected wounds, which has been proven efficient."

It must be borne in mind in reading the above statement by Morison that his observation of war wounds had been confined to soldiers who have been evacuated to England (Northumberland) so that by the time cases reached him they were already infected and a more or less copious suppurating process had already been established. We are more concerned with the treatment of comparatively recent contaminated wounds as yet relatively free from suppuration and phlegmon.

After a trial of many antiseptics and vehicles Morison finally adopted as the most successful and the least toxic—bismuth-iodoform-paraffin paste. It should be stressed that Morison was primarily interested in curtain drainage and that he believed the essential constituent of the past to be paraffinum liquidum. It is evident that substitution of this substance by paraffinum molle (vaseline) hardly justified the claim of originality which at least one contributor has made. Since a paste which will adhere to the dehydrated tissues is required, it is important that liquid and not soft paraffin be employed if the effect originally planned by Morison is sought.

Since Morison's original aim was to permit safe closure (by suture) of suppurating wounds, it was essential that curtain drainage be obtained by means of a paste which would adhere to dehydrated tissues and so permit the paraffin to remain *in situ*.

RUTHERFORD MORISON'S B.I.P.P.

| | |
|---|---|
| Bismuth subnitrate | 1 part |
| Powdered iodoform | 2 parts |
| Liquid paraffin | about 1 part |

To make a paste which will adhere to dehydrated tissues.

*Essentials of Rutherford Morison's Technic.* The essentials of Morison's technic are: (1) Free exposure of whole wound including bottom and all interstices; (2) removal of foreign bodies and dead tissue; (3) hemostasis; (4) dehydration by means of alcohol; (5) careful application of B.I.P.P. to whole surface; (6) removal of all excess B.I.P.P.; (7) suture unless contraindicated, and (8) fixation splint or plaster.

An article by Colledge and Drummond[10] was one of the first published (July, 1917) regarding the employment of B.I.P.P. in the immediate treatment of wounds at a Casualty Clearing station. The technic described by Colledge and Drummond was typical of that used by most surgeons at Casualty Clearing stations. I believe that I cannot do better than quote from their article. It will be noted that at this time the addition of liquid paraffin soaked gauze had not been employed.

"The patients usually arrive in a filthy condition, encrusted with mud. The skin around the wounds, for now they are usually multiple shell, bomb, or grenade wounds, is cleaned with ether soap and rendered as surgically clean as possible. The part is surrounded with dry sterilized towels. Surrounding the entry and exit wounds there is always a margin of necrotic skin heavily infected with micro-organisms. This is removed by excising a ring of skin one-eighth of an inch wide. The wound is then freely opened up and all foreign bodies and loose pieces of bone are as far as possible removed. Further, all devitalized muscle is resected and bleeding points are secured with Spencer-Wells artery forceps. This resection extends not only to muscle which is obviously necrotic, but also to areas which are devascularised and non-contractile. It is in muscle in this condition that gas gangrene begins to spread. Although this procedure is most important, the writers have had long enough experience to know that in itself it is insufficient to prevent the subsequent development of obvious signs of infection in compound fractures.

"The raw surface is then well swabbed with methylated spirit, and the B.I.P.P. is smeared all over the wound and the ends of bone with a piece of dry gauze. It should be well rubbed in to form a thin film on the surface, and care should be taken not to leave any excess.

It is convenient to leave the ligaturing of bleeding points until this stage, as otherwise the ligatures are apt to be rubbed off. Gaps in muscle can be brought together with catgut stitches when necessary.

"The wound is then sewn up with interrupted fishing-gut sutures and a dressing of dry sterilized gauze is applied; this is covered with wool and a splint is applied. In a favourable case the dressing need not be disturbed until the patient is evacuated to the base. If the outer dressing becomes stained with discharge it should be changed without disturbing the gauze in contact with the wound. If the patient has to be evacuated immediately to the base it is advisable to insert the fishing-gut stitches, but to leave them untied or only loosely tied. They can then be tightened later on without fear of tension being caused in the wound by retained discharge. This applies particularly to very extensive wounds."

These authors, both of whom were personal friends in France, conclude with the following statements:

"The B.I.P.P. method is the simplest and most reliable the writers have had the opportunity of employing of avoiding suppuration in infected gunshot wounds.

"It contributes greatly to the comfort and well-being of the patient for the following reasons: (a) wet dressings and irrigations are avoided; (b) as the dressings need seldom be changed there is a minimum disturbance of the injured part.

"It greatly increases the facility and reduces the discomfort of transport. Apart from wounds of the viscera and central nervous system, the management of compound fractures presents the most difficult problem for the surgeon in a Casualty Clearing station, and it is in this class of cases that the writers have found the method particularly valuable."

Since McKim and I have already indicated our attitude with regard to Morison's paste and liquid paraffin gauze packing, no further reference to this form of curtain drainage will be made here.

*Orr's Contribution.* Perhaps the most generally publicized method of employing curtain drainage has been that modification of Morison's method with which the name of Orr is associated.

Orr substituted soft paraffin (vaseline) for the liquid paraffin introduced by Rutherford Morison and those who developed his method. Due probably to the occasional unfavorable developments as the result of iodoform or bismuth poisoning in cases in which B.I.P.P. was improperly used, he avoided the employment of an antiseptic. The foul odor which characterizes wounds treated in this

way is at least one result of the removal of bismuth and iodoform. Orr's technic depends upon three important principles: (1) Adequate mechanical (operative) treatment of the wound; (2) curtain drainage —soft paraffin packing, and (3) fixation—plaster of Paris.

There can be no doubt that Orr did, in fact, make a fundamental contribution in his insistence upon absolute fixation by the employment of plaster of Paris in older infected wounds. At the same time enough has been said, I believe, to indicate that in the opinion of many surgeons under battle conditions, in highly cultivated terrain, such a technic will require extremely careful judgment on the part of the surgeon employing it. It is, in fact, difficult for those of us who treated large numbers of wounded in France and became familiar with the horrors of gas gangrene to believe that methods of fixation other than traction by means of Thomas splints or one of the modifications thereof will be used when the battle period starts in the west.

*Trueta's Contribution.* During the Spanish War Trueta, of Barcelona, employed a method and has happily presented an adequate description of his technic to the surgical world and consequently to surgeons in the Medical Services of the army, navy and to those responsible for the care of air raid casualties. Since Trueta has published his technic in detail, together with the results obtained by him in over one thousand cases most of which were air raid casualties in Spain, it will not be necessary for me to describe his work in any detail.

Trueta's technic is essentially, I believe, summarized in the following way: (1) Adequate and somewhat radical mechanical (operative) treatment of the wound; (2) prevention of sealing of wound—gauze packing or rubber tubes, or both, and (3) application of unpadded plaster—usually moulded.

Trueta's contribution has shown more clearly, I believe, than ever before the importance of almost absolute fixation of the tissues, both bone and soft tissues, and prevention of edema in assisting them to control and limit the infective process.

However, I believe it should be borne in mind that Trueta's cases were chiefly air raid wounds, and that in consequence the length of time intervening between injury and surgical treatment was short; also, that the clothing and skin of such persons is relatively clean and that there is as a rule a minimal amount of mud and gravel contamination of wounds.

The reports that have arrived from Britain (Ross and Hulbert,[11] Cohen and Schulenburg,[12] Brown, Dennison, Ross and Divine)[13] regarding the employment of Trueta's technic in the case of air raid casualties, though as yet incomplete, would indicate that the method has proved its usefulness.

There are many laudatory reports from British surgeons regarding the value of Trueta's publications, and more especially regarding their appreciation of the contributions which Trueta is making to the present British war effort. I quote from remarks made by Sir Thomas Dunhill[14] who gave an account of sixty-five patients treated at his hospital, all of whom were regarded as extremely ill:

"They were patients whose knees and elbows were shattered and ankles broken. They were in a very unhappy condition on arrival; pus was soaking through the plaster to the beds, and the stench in the wards was beyond belief. In the last war he would have felt that three-quarters of these men would require to have their limbs amputated at once, and that streptococcal septicaemia would occur. There was no question of treating them in the Trueta fashion, but it was desired to see what fixation would do. Their condition was assessed as quickly as possible, the worst being dealt with quickly. Two died from secondary haemorrhage during the ensuing few weeks, and one from gas gangrene on the night he arrived; but apart from these three none of the sixty-five died. Their tongues were dry, their skin was the skin of poisoned people; they had no appetite and were in pain. A number got rigors, and when this occurred the plaster was taken off; if the drainage could be improved this was done, and the plaster reapplied. They all had a sulphonamide drug to begin with, which was stopped after a number of days when it was felt that the appropriate doses had been given. A good many times when rigor occurred he thought there was septicaemia, but it was not septicaemia, it was bacteriaemia, which he believed was controlled by the sulphonamide which was given. Often he thought that amputation should be done. Yet not one had died, all were walking with some kind of apparatus, and there were very few in whom the wounds had not dried completely. Their tongues were clean, their colour good, and their demeanour cheerful. There was no doubt that the haemolytic streptococcus had been there all the time, but it had been controlled. He believed the result to be, as to three-quarters of it, due to fixation, and, as to the remaining quarter, to the sulphonamide preparation, which, with fixation, seemed to be able to

scotch the spread of infection. In not one case was amputation done."

*Sulfonamides.* Since there was much evidence during the War of 1914 to 1918, and since further evidence has been accumulated in civilian practice since that time that a combination of infection by Bacillus aerogenes capsulatus (Clostridium welchii or perfringens) and Streptococcus hemolyticus is of greater importance than infection by either of these micro-organisms alone, and this both with reference to death of the individual and wound repair, and since sulfanilamide has proven itself to be of great importance in controlling streptococcal infections, it would seem evident that the proper administration of the latter drug must bear a prominent place in the treatment of wounds in this war. Whether the most suitable method of employment will prove to be per oram, local application or by the intravenous route must, I believe, continue to be considered *sub judice.*

In this connection, as well as others, I quote from a recent memorandum by Mr. W. H. Ogilvie,[15] of London. Ogilvie, in speaking of his clinical experiences after Dunkirk, said that most surgeons were thinking in terms of the last war; and when they considered how the present war differed from the last, infection seemed to be far less of a problem. The explanation was not so simple. The wounded were less tired and dehydrated; their clothes were cleaner, many of the weapons were far less damaging to the tissues than the shell and hand grenades which formed nearly the whole of the destructive armament of the last war. But after making these allowances much of the credit must go to chemotherapy.

This opinion was based on the observation of about 300 wounded, almost entirely from Dunkirk. Chemoprophylaxis when started early, unaccompanied by any form of treatment, put the cases into good condition, while those who arrived at the hospital infected, in whom chemotherapy was started immediately after operation quite early showed a state of repair and clean granulation which allowed of closure by approximation or grafting.

The wounded from Flanders and Dunkirk were seen never earlier than three days and most of them five days after being injured. Many had been operated on, others had relatively unimportant wounds and were fit to travel. Of the remainder there were two groups: those who had had sulfanilamide, and those who had not. About fifty had had sulfanilamide in varying doses; some had had it at once, others in transit; in some it had been continued regularly, in

many it had been irregular. But considering the late stage at which these cases arrived they were surprisingly fit and the infection of the wounds was minimal. The majority of the wounds were caused by bullets, the weather was dry, many were wounded in sand and on board ship; but even allowing for these circumstances, the contrast between these men and those who arrived at Rouen in 1918 was astounding, and the contrast between those who had been given a sulfonamide in transit and those who had not was almost equally so. The men who had had no sulfonamide drug and were admitted to the hospital two or three days after being wounded were most heavily infected. After being given a sulfonamide drug the patients had a temperature which rarely went above 100°F., and a pyremia which seldom lasted for more than three or four days. If it lasted for ten days, it was nearly always due to the pocketing of pus. Chemotherapy had, however, produced a new lesion, the "sulfonamide" abscess. It was a cold abscess, and when opened contained an odorless pus. The dose Mr. Ogilvie gave was three tablets, .5 Gm. crushed, to start with, followed by two tablets every four hours for forty-eight hours, and one tablet every four hours for the following forty-eight hours. Among the many wounded patients treated with this dosage there were no complications.

Colebrooke whose early work had much to do with the discovery of sulfanilamide and its action, in answering questions made certain memoranda. He said that he would hesitate to use more than 20 Gm. in a sulfanilamide pack, and he did not suppose there was any advantage in using more. For preventive purposes it was best to give one or two doses by mouth. He did not think protosil soluble had merits for quick absorption. If sulfanilamide was given in solution, it was absorbed in two or three hours. He had little to say with regard to sulfonamide ointments. Sulfanilamide was absorbed quite well from a greasy base. A question had been asked as to the treatment after putting on powder. At his hospital they simply powdered the wounds, and put on a moist saline dressing, covering it with jaconet. This was done to maintain the activity of the leucocytes, which was encouraged by keeping the wound slightly moist. Since Colebrooke is an advocate of sulfanilamide introduction into wounds his comments are, I believe, valuable.

We have not had sufficient experience in the use of the sulfonamides in wounds to warrant any opinion whatever. We have employed sulfonilamide prophylactically by mouth in all lacerated

wounds and some of the members of my staff have introduced it into wounds as a powder. No unfavorable effects have been noted.

## CONCLUSIONS

In conclusion I wish to formulate our attitude toward the treatment of severe lacerated wounds whether associated with bone injury or complicated by lesions of other important structures, or not. These conclusions are based upon both personal experience and an effort to evaluate the contributions of other authors:

1. It must be urged that adequate, skilful, rapid operative treatment of the wound is of paramount importance. Such interference must remove foreign material and devitalized tissue and anticipate the development of interstitial tension.

2. Fixation must be obtained; the method adopted for this purpose will depend upon many variables. In general, it may be said that during battles traction should be employed but that for air raid victims and under other circumstances when early operation, leisurely surgery, and maintenance of casualties without evacuation for five days or more may be carried out, unpadded plaster of Paris is apparently safe and is perhaps to be preferred.

3. The prevention of edema and tension should be assisted by firm paraffin packing into the depths of wounds, the employment of pressure bandages or unpadded plasters and by posture. If plaster of Paris is used, windows must not be cut.

4. Bismuth-iodoform-paraffin paste is effective in controlling and preventing infection; it is safe and harmless if properly used and if too large surfaces are not exposed to its action. Of all the ancillary methods of wound treatment with which we are familiar, the employment of B.I.P.P. and liquid paraffin gauze packing is the most reliable, least dangerous and most easily applied.

5. One or other of the sulfonamides should be administered by mouth as a prophylactic and also in the treatment of established infection. The standardized precautions should be adhered to in their employment.

6. Both prophylactic and therapeutic employment of sera—antitetanic and antigangrene—is recommended. The necessity for the former among soldiers immunized to toxin is perhaps still unsettled.

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Note: The two following papers were also presented at the convention in May, 1941, but due to pressure of work could not be prepared in time for this issue: "Carpal Fractures as Seen in the Naval Service," by Commander F. R. Hook, U.S.N., Washington, D. C., and "Subcutaneous Traumatic Injury of the Abdominal Viscera," by Dr. Mims Gage, New Orleans, Louisiana.

Dr. Hook's paper was discussed by Dr. Laurie H. McKim, Dr. Preston A. Wade and Dr. Gordon Murray. Dr. Gage's paper was discussed in conjunction with the article by Dr. Palmer.

# Original Articles

## FRACTURES OF THE ELBOW

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NEW ORLEANS, LOUISIANA

DURING the past thirty years I have essayed many times to discuss experiences about fractures of the elbow. Methods change with improvement of technical details, with accumulated scientific data and with increased experience. Fundamental anatomic knowledge and physical principles remain unchanged.

It is probably more important for us to consider and to teach fundamental anatomic principles today than it was in the past. The ease with which one can resort to *x*-ray examinations gives many a false sense of security and predisposes to the habit of casting aside clinical examinations in favor of conclusions based on inadequate examinations.

Now that surgery of trauma is considered in its proper place there is an ever increasing desire on the part of competent surgeons to care for fractures rather than transfer the responsibility to the neophyte.

A discussion of fractures of the elbow should include epiphyseal fractures, supracondylar fractures, intercondylar fractures, fractures of the head of the radius, fractures of the olecranon, the coronoid process and fractures of the upper portion of the shaft of the ulna.

Basically, we must remember that in order for a joint to function normally there must not be any alteration in position of the articular surfaces which enter into the formation of the joint. Any change in the axis of an articular surface is bound to produce a partial or complete ankylosis of the joint.

There are four groups of elbow fractures which will regularly produce partial or complete ankylosis unless a definite effort is made from the onset to avoid such a disability. These are: (1) Fractures in children with displacement of an epiphysis; (2) supracondylar fractures, either comminuted or simple in which complete reduction is not accomplished; (3) fractures with displacement of a free fragment

which acts like a foreign body wedged between the articular surfaces. In this group we find fractures of the coronoid process, the internal condyle and fractures of the head of the radius; (4) fractures of the ulna, particularly, the upper third of the shaft.

In order to evaluate the significance of injuries about joints in children one must be familiar with the time of the appearance of various epiphyses, the time of fusion and complete ossification with the diaphysis, and the relative position of the epiphysis to the diaphysis.

Even though there has been for more than twenty years studies and pictorial monographs available for study and for teaching purposes, little attention is still paid to this subject in many schools. It is easy, if one is not familiar with the normal appearance, to consider that a fracture exists and the reverse is also true that misinterpretation often leads to the statement that "no fracture exists." The outstanding result is that too much dependence is placed upon the *x*-ray to the exclusion of clinical manifestations. *It is essential to maintain that the clinical examination is still of paramount importance in fractures about the elbow in children.*

In order to substantiate my statement that clinical examination is paramount it will be necessary to repeat statements which have been made many times before with reference to the appearance of the elbow in children.

The only epiphysis which is apparent prior to the fifth year is the capitellum. The relationship of the capitellum to the shaft and the sigmoid fossa of the olecranon alters definitely with approach to adolescense and adult life. In early life (up to the sixth year), a plane passed through the long axis of the middle shaft of the humerus lies behind the capitellum. As we approach complete development of the capitellum this plane either bisects the capitellum or two-thirds of it is anterior to the midplane.

Normally, in very young children there is a definite space between the capitellum and the sigmoid cavity. If there is an overlapping of the shadow of the capitellum by the sigmoid cavity, when the elbow is flexed at right angles, the implication is that there has been a fracture with displacement and, if union has occurred, there is vicious union.

The relationship of the internal epicondyle to the internal oblique line of the shaft of the humerus is of importance from a diagnostic standpoint. Normally, the internal epicondyle, which begins to ossify about the ninth year, is closely approximated and is continuous with

the internal oblique line. If there is a separation with displacement of the internal epicondyle, there has been a fracture. Under these conditions it acts as a foreign body and if it cannot be replaced removal is indicated. Removal of the internal epicondyle does not interfere with function of the elbow nor does it cause an alteration in the carrying angle if the structures about the elbow have not been injured.

A common source of confusion is the appearance of the epiphysis for the olecranon. It sometimes ossifies through two separate centers, more often, however, it ossifies through a single center. Ossification proceeds from the tip downward; the lower posterior aspect of the olecranon epiphysis is the last point of complete fusion. Not uncommonly one will find a report of a fracture of the olecranon which does not exist. These errors are due simply to the failure to interpret properly the normal appearance. The conclusion is inescapable that it is our duty to pay more attention to clinical examination and interpretation of the loss of function, localized pain and other objective phenomena than to depend solely on the *x*-ray.

Failure to reduce a deformity and restore the normal axis and relationship of the epiphysis to the diaphysis will result in ankylosis of the elbow. It is true that removal of an epiphysis, such as the epicondyle, is not desirable, but removal is preferable to an ankylosed elbow.

Operative intervention in fractures involving an epiphysis is not desirable because premature ossification results. Failure of the extremity to develop normally is certainly an undesirable result.

Supracondylar fractures form probably the largest group which we have to deal with among the injuries about the elbow in children. Immediate attention to these injuries is essential if we are to obtain the best results.

Early reduction, that is, within the first few hours, is of paramount importance. Delay means swelling, and this interferes with maintenance of the position of greatest stability.

It has been generally agreed for many years that the position of greatest stability is one of hyperflexion. In that position the triceps, the biceps and brachial anticus act as natural splints to maintain proper reduction. It is not sufficient to say hyperflexion alone. If the fracture involves the internal condyle, hyperflexion and complete pronation are indicated. If it involves the external articular surface, hyperflexion and supination are indicated.

There are several details which must be observed at this point. If hyperflexion interferes with the radial pulse, it cannot and should not be used. The danger of Volkmann's ischemia must be definitely considered.

Before entering into a discussion of the dangers of Volkmann's ischemia, a word about the dressing which has been utilized by us for many years may not be out of place. All bandages should extend from the finger tips to the shoulder. No splint is used in the bend of the elbow; a simple bandage, sheet wadding, bandaging the entire upper extremity as a stump is essential. Any bandage which begins at the wrist or ends at the wrist is dangerous. As swelling occurs a vicious circle results; the greater the swelling, the tighter the bandage, and more swelling of the hand will result. This can be definitely avoided by including the hand in all dressings and by avoiding the use of a gauze bandage sling, substituting for this a soft rubber tubing as a halter around the wrist and neck.

For more than twenty-five years it has been a practice with me to have a bag sling made to cover the dressing; this avoids the bandage slipping and permits free motion of the shoulder. It is important in these cases to begin shoulder motion from the earliest time, particularly rotation. Prolonged internal rotation at the shoulder permits contracture of the internal rotators and a stretching of the external rotators of the shoulder; and even though the patient has complete extension of the elbow, internal rotation at the shoulder causes the elbow to be held out thus giving a deformity which has nothing to do with the elbow injury. This deformity results from failure to give proper attention to the muscles about the shoulder girdle. There may be those who will disagree with this point. Personal experience has demonstrated the value of this detail.

Volkmann's ischemia, though not a frequent experience with most of us, is of such grave importance that when it does appear we should not overlook anything which might prevent this disastrous complication. It is preventable in most instances. There was a time when tight bandages were held responsible. Many theories have been advanced as to its etiology. Up to the present time no single etiologic factor has been demonstrated. Since the earliest manifestation may appear within the first few hours after the injury, it is important for the surgeon in attendance to be mindful of all of the factors which have been considered as possible provocative means for its production.

Volkmann, in his original description, expressed the belief that there was an interference with the arterial circulation thus robbing the muscles of oxygen and causing their death. He later indicated that he believed that there was in addition to an interference with the arterial blood supply an obstruction of the venous outflow.

Stephen Jones, of Boston, (1939) concludes "*Volkmann's ischemia occurs in the absence of splints or tight bandages.*" *This conclusion is accepted by practically everyone.* He believes that it is caused in certain cases by interruption of circulation. He does not believe that it is due to a complete obstruction of a main artery. He bases this conclusion on the accepted fact that dry gangrene and flaccid paralysis result from obstruction of the main arterial supply. *He believes that the interruption of circulation or supply to the muscles may be due to intrinsic pressure upon the circulation caused by hemorrhage within the fascial envelope.* Based on this opinion he, with most others, believes that the operation of fasciotomy performed early gives an opportunity for collateral circulation to develop and avoids interference with oxygenation of the muscles which would result in the muscle changes characteristic of the condition.

Leriche advanced the idea that the condition was due to arterial spasm and accordingly advocated removal of sympathetic influences.

The outstanding studies of this subject have been made by Barney Brooks (1922) and by Griffiths (1940).

Before discussing these two studies it might be well to call attention to the fact that from the earliest period of investigation of Volkmann's ischemia certain facts with reference to the histologic findings have stood out. As early as 1884, Lesser, and again in 1907, Powers had occasion to study muscles removed from patients who had Volkmann's ischemia. *The outstanding findings were hyperplasia of connective tissue around and between muscle fibers and a marked inflammatory process in the muscle.*

In all Brooks' experimental work several things stand out plainly: "In no instance was there found marked inflammatory reaction or fibrous change in muscle in which permanent ligature of a large artery was done leaving the vein intact. In cases in which the vein alone was ligated, there was a marked inflammatory reaction evidenced by an accumulation of polymorphonuclear leucocytes and at a later stage large amounts of fibrous connective tissue were found.

"The result of the obstruction of the vein of the isolated muscles with the preservation of the artery is different from any result

obtained by artery occlusion. Under these conditions there was found a pathologic change, the outstanding features of which were hemorrhage, edema, degeneration of muscle fibers and an acute inflammatory process which progressed to a more or less complete fibrosis of the muscle.

"This fibrosis is associated with contraction and loss of power of the muscle. This process may convert the muscle into a veritable fibrous band which is incorporated in a similar fibrosis of the surrounding tissue. Permanent occlusion of a large artery is not followed by acute inflammatory disease. Anemia and inflammation are incompatable pathological processes. Any condition, therefore, which developes within twenty-four or forty-eight hours, and which is characterized by heat, swelling, pain and a subsequent fibrosis, cannot be the result of permanent occlusion of an artery. 'The classic picture of Volkmann's ischemia paralysis could only be explained on the basis of acute venous obstruction.'"

Middleton, in 1930, repeated experiments similar to Brooks and supported the views expressed by Brooks. Griffiths, in 1940, stated: "I cannot accept the conclusion that the lesion produced was a Volkmann's contracture."

Griffiths' clinical experience with Volkmann's ischemia is limited to a single case in which the patient was operated upon as early as the fourth day. The majority of cases which he saw were late cases. In the one four-day case there was no subfascial hemotoma. He is rather dogmatic in his statements: "The obstruction to venous return theory simply cannot stand." . . . "All the reports of early cases operated on in this country (England) and even elsewhere, the discovery of such a hemotoma is a very rare event. Instead what has been found by operators exploring early cases of Volkmann's syndrome is arterial obstruction."

Griffiths' statements are based on a rather extensive experience with cases after arterial injury and embolism. He has operated upon twenty patients in whom there has been an arterial occlusion due to embolism. "Three patients despite apparent successful restoration of the circulation developed typical Volkmann's ischemic contracture after embolectomy." He concludes as follows:

"Volkmann's contracture is due to arterial injury and reflex spasm."

Based on the above belief he advocates wide incision of fascia in the antecubital fossa and the adequate exposure of brachial, radial and ulna arteries in every case.

Garber and Steindler (1939 and 1936, respectively), have taken a very temperate view. Garber advocates fasciotomy and Steindler insists that one of the most important things in the avoidance of the condition is never to use a flexed position immediately after the accident.

There are two or three points which are important to us as teachers: Since there is a difference of opinion as to the etiologic factors in the production of this pathologic condition, it is essential that we try to avoid all of the possible causes.

With Volkmann's contracture in mind we should proceed with: (1) Early adequate reduction, prior to the onset of swelling; (2) avoid tight bandages; (3) if there is any interference with the radial pulse, acute flexion should not be used. That position in which one has an adequate radial pulse is the only position which is tenable. (4) If the swelling exists in the antecubital fossa and the radial pulse is absent, fasciotomy should be done. (5) I believe that it would be dangerous teaching to advocate exposure of radial, ulna and brachial arteries in these cases. These fractures are first seen by the general practitioner. If we advocate extensive exposure of major vessels, harm is bound to result.

American reports do not indicate that it has been necessary to expose the brachial artery after fasciotomy.

### FRACTURES OF THE HEAD OF THE RADIUS

Fractures of the head of the radius are important injuries about the elbow because of three factors: (1) Many incomplete fractures of the head of the radius are overlooked and are considered as sprains or contusions of the elbow. (2) Fractures of the head of the radius in which there is a displacement require removal of the head of the radius. (3) Radial nerve paralysis is not infrequently associated with fractures of the head of the radius if there is an anterior dislocation of the radial head.

For the above reasons it is important to make a careful examination and to consider the possibility of a fracture of the head of the radius, even though no gross deformity exists, when there is limitation of pronation and supination and localized pain over the head of the radius. It is just as important for the future function of an elbow that immobilization be employed in such a case as if gross deformity existed. Such patients, if untreated, will experience some limitation of motion, particularly, pronation and supination, at a later date on account of exuberant callus which may be formed.

There are two important complications which result from displaced radial heads: The radial head acts as a wedge limiting motion of the elbow and the radial nerve may be stretched producing either temporary or permanent paralysis of its peripleral distribution.

The anatomic approach to the head of the radius so as to avoid injury to the radial nerve is urgent. Injury by stretching from unnecessary retraction is to be avoided just as assiduously as section through an improperly placed incision. Flexion of the elbow to a right angle and pronation of the forearm is the position which offers the greatest ease of approach to the radial head.

The fundamental principles outlined by James E. Thompson, of Galveston, Texas, for the approach to long bones should be observed. The incision for removal of the displaced radial head should be made so that the supinator muscle through which the radial nerve passes can be retracted forward. If there is any question as to the location of the nerve, dissection upward should be done so that the nerve can be seen prior to its penetration of the supination. (Further details of the approach are found in description of operation in Case 1.)

### FRACTURES OF THE ULNA

Fractures of the upper third of the ulna must be considered when one is discussing fractures of the elbow. Attention has been called many times to the fact that anything which causes an alteration in the axis of one of the articular surfaces entering into the formation of a joint produces limitation of motion of that particular joint. This is especially true in fractures of the upper third of the ulna. In these fractures there is a definite pendulum swing of the upper fragment to the radial side. This is, in part, due to the contraction of the anconeus and supinator brevis which originate from the external condyle and are attached to the upper fragment of the ulna. The contraction of these muscles produces radial deviation of the upper fragment, which in turn is flexed by the brachialis anticus and biceps. The deviation thus produced alters the relationship of the sigmoid cavity to the articular surface of the humerus, thus limiting motion.

In order to have a normal functioning elbow following such an injury it is necessary that an anatomic reposition of fragments be obtained. This is one fracture which I believe definitely needs an open operation, as most of them cannot be reduced adequately by conservative measures. There are times when there is an associated fracture of the head of the radius with such fractures of the upper third of the ulna.

*Operative Exposure.* The operative exposure I have used for fifteen years follows: The method of approach consists of two separate incisions, if the upper ulna fragment is very short. The first is a linear and the other a semicircular incision which extends from one condyle to the other. The relation of the two is such that the linear incision meets the semicircular at its pole. When only the skin has been incised, the outline resembles a flag staff on a mound. At times a single posterolateral incision has been sufficient. The position of the forearm is important. The elbow is flexed and the forearm is midway between pronation and supination. This permits approach to the shaft of the ulna along the posterior ridge between the flexor profundus digitorum, extensor carpi ulnaris and anconeous. The shaft of the ulna is thus reached without injury to the muscles.

The semicircular flap of skin and superficial fascia is reflected. The muscles on either side of the linear incision are reflected and with them the radial and ulna nerves are retracted out of harm's way. The upper fragment which consists of the olecranon and the attached triceps is reflected slightly. The joint surface of the lower end of the humerus can then be exposed and with a retractor introduced the vessels in front of the elbow can be lifted up, permitting access to the front of the joint for the purpose of removing fragments of the head of the radius or of the coronoid. Retraction in this way avoids injury to the vessels which lie in front.

Other details relative to the particular method of approximating the fragments of the two ends of the fractured bone will be approached according to the particular habits of the operating surgeon.

The advantages of this incision are that it permits an approach to the joint without injury to important muscles or vessels and that it is not necessary to expose the nerves as they are retracted with the muscle.

If the ulna fragment is long, a single posterolateral incision is used. The technic is illustrated by the following case:

Case 1. Mrs. E. K., age twenty-eight, was first seen by me May 18, 1933. On March 26, she had fallen on the outstretched hand and was immediately placed in the care of a surgeon who, the following day after manipulating the part under anesthesia, applied a plaster cast to the arm and forearm at a position of about 130 degrees. The cast was worn for about four weeks, after which it was cut in half and the arm was manipulated twice a week for three weeks, at the end of which time she was able to flex the elbow not beyond 120 degrees and extend it not beyond 150 degrees. There was complete loss of pronation and supination.

On examination atrophy of the arm and forearm was noted, a marked varus deformity of the elbow could be seen and there was a marked conical enlargement of the elbow with a fullness in the antecubital fossa. *X*-ray at this time showed an old fracture of the ulna with a pendulum swing to the radial side of the upper fragment, a fracture of the coronoid process and a fracture of the head of the radius with a free fragment just below the head of the radius. Preoperative Diagnosis: Fracture of the head of the radius and ulna—vicious union. Operation was done on May 26, 1933.

An incision was made over the ulna about four inches long, beginning just below the olecranon. The periosteum was retracted on the radial side and with it the anconeous and supinator muscles. The radius was then seen and, subperiosteally, the shaft was displaced and brought into the wound and the orbicularis ligament was then cut and the head of the radius that was free was easily removed. The proximal end of the shaft was then smoothed off with rongeur and rasp and bone wax applied over the cut end. The ulna which we could see showed the site of the old fracture about one and one-half inches below the tip of the olecranon. There was an angulation of about 130 degrees between the upper fragment and the lower fragment. The union between these two fragments was very slight. The fragments were separated by the slightest bending movement of the fibrous tissue, and muscle on the anterior aspect of the upper fragment was separated from it. We also noticed a large piece of exuberant callus on the ulnar side of the distal fragment which was removed. We found another fracture of the sigmoid cavity and as we looked at the two fragments we realized that if we put a plate in with the screws, they would have to be extremely long, and more than that, a portion of the proximal fragment was so thin that the screws would have no definite hold on it. For that reason, it was decided to follow the plan I have adhered to before, using drill holes transversely, and particularly in the long axis of the bone in the upper and lower fragments. Iron wire was passed through and with U-sutures through both of these sets of drill holes the remains of the orbicular ligament was sutured to the posterior portion of the capsule. The fascia was approximated with interrupted chromic catgut. The skin was approximated with interrupted Burdick-Davis-Blair sutures and a plaster cast applied. Note: There was not a single large blood vessel injured in the whole procedure.

*End Result.* At the examination made May 10, 1941: "Patient is able to carry on her usual activities: playing golf, driving an automobile, swimming and rowing. She is able to extend the elbow to about 150 degrees and flex it to about 45 degrees. There is definite limitation of pronation and supination. *X*-ray picture taken at this time shows a synostosis—radius and ulna, and an old fracture of the ulna well healed."

*X*-ray Consultation, May 10, 1941. No. 69124: "Examination of the left elbow reveals evidence of old healed fractures of the olecranon, coronoid and upper radius. There is solid bone union. The olecranon is inclined

somewhat forward and at its base there is noted a wire loop embedded in the bone. A small step formation in the articular cortex identifies the site of the coranoid fracture. The articular cortex otherwise is smooth. The head of the radius has been removed, the proximal portion of the shaft being fused to the ulna. A bony ledge is seen to project anteriorly just below the coranoid process. The carrying angle is preserved."

*Comment.* Much time could have been saved and disability avoided if patient had been operated upon promptly.

Fractures of the lower end of the humerus in adults presents a very different problem from supracondylar fractures in children. The majority of supracondylar fractures in adults are of the flexion type and are often due to direct violence applied to the posterior aspect of the arm. There is often multiple comminutions as well as injury to the triceps muscle.

The method of treatment to be adopted in individual cases depends on several factors: notably the age of the patient, the amount of soft tissue damage at the time and the comminutions as well as displacements of fragments. It has not been my good fortune to be able to reduce these fragments and maintain reduction by the simple closed method in the majority of cases. Each case must be individualized. If there are multiple comminutions and displacements, direct skeletal traction (Kirschner wire) through the upper portion of the ulna just below the olecranon process in addition to suspension and lateral traction of the Russell type has been the primary method of choice. If reduction with this method cannot be satisfactorily obtained and maintained, open operation is indicated if the fragments are not too numerous.

In those cases in which open operation is advisable, I believe that the posterior approach as advocated by Van Gorder is the most desirable method of approach. It is true, it permits exposure of the entire posterior aspect of the shaft and the condyle with the minimum damage to important structures. It is advantageous because it avoids violent retraction. The procedure does not interfere with future flexion or extension of the elbow.

In order to illustrate the above statement a few cases will be briefly described and the method of treatment in each submitted.

CASE II. Mrs. E., age seventy-six, April 29, 1938, fell in her own home and struck the elbow from behind. Immediately there was loss of function and on examination there was a marked increased anteroposterior diameter of the right elbow and marked angulation of the lower portion of the arm. Immediately after preliminary inspection and palpation an *x*-ray was taken.

This revealed marked comminution of the lower end of the humerus, with the shaft of the humerus displaced downward between the fragments. The lateral view showed marked posterior displacement of the forearm with backward angulation and upward displacement of the forearm on the shaft of the humerus. It seemed evident that the only method available for this case would be direct skeletal traction. At once a Kirschner wire was introduced into the upper portion of the ulna, a sling was applied to the arm for the purpose of making use of suspension and traction of the Russell type. The forearm was suspended so that it would be as nearly as possible at right angles to the arm.

The progress of the case so far as the effect of the traction is concerned is illustrated by the *x*-ray pictures taken during the course of the treatment.

It seemed that any other operative intervention was not to be considered because of multiple fragmentation. The end result justified the method of treatment as the patient has almost (150°) complete extension and flexion beyond 45 degrees. The result is not perfect but it is better than I anticipated. It is better than any method that I know of for the management of such cases.

It is well for us at times to take stock and see what changes time has made in our method of handling individual cases and how much better results may have been obtained if we had handled an individual case in a different manner.

Case III. Mr. N. O. B., age approximately forty, December 18, 1920, fell from a scaffold for a distance of twenty-five feet, sustained a compound fracture of the left humerus, laceration of the triceps tendon, lacerated scalp wound and a fracture of several ribs. The *x*-ray picture showed multiple comminuted fractures of the lower end of the humerus and the shaft was displaced downward between the external condyle and the trochlear process.

The immediate treatment at that time (1920) consisted of débridement of tendons and immobilization of the part in hyperflexion. Pictures taken the following day showed a displacement forward of the condyles and the lower fragment and an increase in the overridding deformity. Noting this displacement a Jones elbow extension splint was applied with a pressure pad on the forearm for the purpose of obtaining traction and if possible increasing the distance between the shaft and the distal fragments.

By March, 1921, he was able to extend the forearm on the arm at 160 degrees with a posterior angulation and considerable limitation of motion of the elbow. About one year later December, 1921, an arthroplasty was done. The technic was that suggested by MacAusland of Boston. A better functional result was obtained by the arthroplasty than the patient had prior to the operation.

In looking back over this experience it is easy to see how this patient may have been treated with comparative ease by introducing a Kirschner wire for skeletal traction and an overhead suspension as was used in the case of Mrs. E. This experience is introduced for the purpose of demonstrating the importance of changing methods with improvement.

CASE IV. D., May 5, 1940, had suffered multiple comminuted supracondylar fractures. The patient was not admitted to Touro until about thirty-six hours after the accident because it occurred about six hundred miles from New Orleans. At once a Kirschner wire was introduced into the ulna and suspension of the Russell type of traction on the arm and suspension of the hand and forearm was applied. After ten days, when it was evident that it would be impossible by skeletal traction alone to accomplish anything like adequate anatomic reduction, it was decided to do an open operation. Preoperative diagnosis: Multiple comminuted fractures of the humerus with intercondylar fracture.

The posterior approach as suggested by Van Gorder was adopted. The patient was placed on her face with the arm resting on the table and forearm flexed at right angles with arm hanging over the side of the table. The incision was made over the posterior aspect of the arm from about five inches above the tip of the olecranon down to the level of the tip of the olecranon process. The skin and subcutaneous fat and fascia covering the triceps was incised. The ulnar nerve was exposed and retracted out of the way, then an inverted U-type of incision was made, the end beginning and ending about the level of the condyle and extending upward above the origin of the tendon triceps. This tongue-shaped flap of muscle and tendon was reflected downward, thus exposing the humerus. There was a great deal of old blood found in the depths. We then found the shaft of the humerus and the end of the proximal fragment was displaced down between the distal fragments. Our first effort was made to approximate the distal fragments and place a screw from the medial aspect to the lateral. This could not be definitely accomplished, because the thickness of the two condylar fragments was not great enough to hold the screws. Finally, we were compelled to put a plate on the shaft fragment and to approximate the shaft fragment and one of the distal fragments. There being nothing else for us to do, through a drill we held the lower fragments as well as we could with a piece of annealed iron wire. The internal condylar fracture seemed to be almost free. There were many small fragments and one or two being free had to be removed. The triceps muscle was then resutured and the skin and subcutaneous fat were sutured and a plaster cast applied with the elbow at right angles. A Kirschner wire was included in the cast.

The end result in this case was flexion to about 30 and 40 degrees and extension to about 170 degrees.

*Summary of Supracondylar Fractures Where Comminution Exists.* (1) Skeletal traction is preferred rather than indirect skeletal traction with the use of adhesive plaster. If adhesive is used and the skin becomes irritated, the danger of surgical approach is definitely increased. (2) If anatomic reposition cannot be obtained and there are not too many comminutions, the use of either a screw or bolt to approximate the two condyles and in addition one or more plates applied from the shaft to the distal fragments is indicated. (3) These are definitely complicated fractures and the treatment had best be undertaken only if one has proper conditions for the treatment.

## CONCLUSIONS

1. In the diagnosis of injuries about the elbow clinical examination should be accorded first place.

2. A false sense of security often results from *x*-ray examinations of elbow injuries especially in children.

3. It is essential to know the date of appearance, the relationship of and the age of complete ossification of the epiphyses in children, if *x*-ray pictures are to be interpreted properly.

4. Alteration of the axis of one of the articular surfaces results in partial or complete ankylosis of the joint.

5. There are four groups of fractures about the elbow which produce partial or complete ankylosis unless reduction is accomplished. These are: (a) Fractures in children with displacement of an epiphysis; (b) supracondylar fractures, either comminuted or simple, in which complete reduction is not accomplished; (c) fractures with displacement of a free fragment which acts like a foreign body wedged between the articular surfaces; (d) fractures of the ulna, particularly the upper third of the shaft.

6. Operation about the elbow involving the epiphyses should be avoided if possible in children.

7. If fractures of the internal epicondyle epiphysis cannot be completely reduced, its removal does not cause disturbance of function of the elbow.

8. Early complete reduction in fractures about the elbow is essential.

9. Every effort should be made to avoid Volkmann's ischemia. If there is evidence of hemorrhage about the joint, fasciotomy should be done. Exposure of the radial, ulna, or brachial arteries is not advocated in suspected cases of Volkmann's ischemia.

10. Fractures of the head of the radius with displacement of the radial head as a rule require resection of the head.

11. Radial nerve paralysis from stretching in cases of fractures of the head of the radius with displacement not uncommonly is a complication of these injuries.

12. A method of exposure for removal of the radial head is described.

13. Fractures of the upper third of the ulna are often associated with a pendulum swing of the upper fragments with a resultant diminution in the carrying angle and partial ankylosis of the elbow.

14. Operation is indicated in many of these cases.

15. Fractures of the head of the radius and fractures of the upper fifth of the ulna are commonly found as associate injuries.

16. The method of operative approach is indicated.

17. Comminuted, supracondylar fractures in adults are not uncommonly associated with a lacerated or a completely severed triceps tendon.

18. The method of treatment to be adopted in individual cases is dependent upon the age of the patient, the amount of soft tissue damage and the comminutions as well as the displacement of fragments.

19. Where there are multiple comminutions, skeletal traction making use of Kirschner wire in the upper portion of the ulna just below the olecranon for lateral traction and suspension, along a modified Russell plan is indicated.

20. If complete reduction cannot be accomplished and there are not too many fragments, operation making use of screws and plates is indicated.

21. Postoperative management includes immobilization until callus is sufficiently formed to allow for active motion.

22. Passive motion is a dangerous procedure.

23. Many forms of physiotherapy are harmful. Heat and gentle massage, plus active motion are the most important procedures to be adopted.

24. The method of approach for operation in comminuted supracondylar fractures suggested by Von Gorder offers the most direct approach and the least damage to anatomic structures.

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## DISCUSSION

ROBERT I. HARRIS (Toronto, Ontario): The field of Dr. Cohn's paper is so broad, and the individual problems so diverse and so important as to make discussion difficult. I propose, therefore, to limit my discussion to one or two of the problems associated with fractures about the elbow, and leave to others the discussion of other problems.

First with regard to the supracondylar fractures which occur in children, so important because they are so common, I agree with Dr. Cohn that reliance upon *x*-ray alone can lead one into a false position. I am sure Dr. Cohn would agree, also, that the use of *x*-ray is essential in the adequate treatment of fracture.

We cannot overlook the clinical evidences of injury to the elbow in children, no matter what the *x*-ray says; but when we have before us the child whose elbow is obviously injured, *x*-ray is an essential aid to our treatment both of the reduction and especially of our determination as to whether the reduction has been adequate.

I find myself in agreement with Dr. Cohn also in believing that if reduction can be attained before swelling has taken place, the accuracy of reduction is better, and the ease of the maintenance of that reduction also is better.

I must say, however, that in holding this opinion, I am in strong disagreement with some of my colleagues, colleagues of great experience, who believe that the danger of Volkmann's paralysis, when reduction is carried

out before swelling has taken place, is so great as to place the surgeon in an undefendable position should Volkmann's paralysis occur.

However, frequently one is faced with the situation in which reduction must be performed after swelling has occurred. We have not the opportunity of seeing the patient, and the swelling has occurred. That is a common problem which must be faced.

It is my experience, in such circumstances, that reduction in stages is eminently successful, that is to say, the fracture is reduced and the elbow flexed as far as possible in the presence of swelling, without interfering with circulation; and after an interval of several days the elbow is flexed further in order to secure and maintain adequate reduction. This may be carried out to a third stage, if necessary.

Volkmann's paralysis is of the utmost seriousness to the patient and to the surgeon. I think it should be stressed that it can occur without the application of splints or bandages or plaster of any sort. Twice in my experience I have seen Volkmann's paralysis occur in association with supracondylar fractures without the application of any form of apparatus.

On one occasion, this fact was sufficient to win for a colleague a suit for malpractice, the knowledge that Volkmann's paralysis can occur without the use of splints.

I believe that Griffiths' work must be accepted with reserve. It has not been our experience that arterial occlusion due to embolism or thrombosis is productive of ischemia. More work is needed on the problem of Volkmann's paralysis, either to confirm Barney Brooks' work, which I believe to be correct, or to throw more light upon the problem.

Dr. Cohn did not mention, at least specifically, the fracture of the upper third of the radius associated with anterior dislocation of the head of the radius, the so-called Monteggia's fracture, important though rare. It is important because we should realize its pathology and realize also that the dislocation at the head of the radius prevents the reduction of the fracture of the ulna, and the dislocation cannot be corrected usually without operation.

J. Dewey Bisgard (Omaha, Nebr.): I want to mention in this discussion, fractures involving the epiphyses of the lower end of the humerus which are so likely to result in some growth disturbance, and as the arm continues to grow this disturbance will cause an alteration of the carrying angle increasing, decreasing or reversing it. Such deformities are usually insignificant but it is wise to warn the parents of the child that a disturbance in growth is likely to take place subsequently. As a result of the alteration of the carrying angle—as has occurred in a number of cases in which there has been a disturbance in growth—there may result many years later a delayed or late ulnar nerve paralysis.

Frank P. Strickler (Louisville, Ky.): I think this is a very important subject and that we ought to have a little more discussion on it.

There is one phase of it that I want to bring up, especially in children. It is over-*x*-raying these children. I do not think you should lose sight of the fact that over-*x*-raying of these cases can produce a disturbance in the epiphyses with the resultant inhibitory effect on the growth of the extremity. I think we should bear this in mind. As far as I know, there is no radiologist who will tell you how much or how little you can *x*-ray these epiphyses without producing an undesirable effect on them.

Another thing I believe Dr. Cohn meant to bring out, but to me he did not make it clear, is that in the ischemic paralysis, the damage many times is produced by the injury itself, and you may develop ischemic paralysis in instances in which the surgeon has nothing in the world to do with it. The damage is produced in the blood vessels at the time of the injury, and you will get an ischemic paralysis whether you use splints or not, or no matter what type of treatment you employ.

I think we ought to consider this phase of ischemic paralysis and have it definitely in mind in all serious cases.

# EVALUATION OF THE "HANGING CAST" AS A METHOD OF TREATING FRACTURES OF THE HUMERUS*

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THE effective treatment of fractures depends upon adherence to principles. Two general methods of treatment of fractures dominate our therapeutic approach, namely, (a) reduction of the fractured bone ends with immobilization which externally may include the joints above and below the fracture and (b) application of traction to the injured part preferably in a position of relaxation. All forms of good fracture treatment belong to one or the other of these types. Much confusion has resulted in consideration of the use of the "hanging cast" method of treatment of fractures of the humerus. Some of this has arisen because the use of a plaster cast suggests that it is a form of immobilization fixation type of treatment. Considered in this light it is obviously in violation of principles. It is, however, one of the best examples of the use of traction in the treatment of fractures, and the humerus of all bones particularly lends itself to this form of treatment.

Traction methods are not new or startling. The use of traction on the humerus is well exemplified by the familiar suspension and traction method of Blake and Bulkley and by the use of the Jones humerus traction splint, as well as the method recently described by Gurd.[1] Since 1933, when Caldwell[2] described the use of the "hanging cast" in the treatment of fractures of the humerus, several series of cases have been reported[3,4,5,6,7,8] all attesting to the efficacy of this form of treatment.

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Although anatomic reposition and rigid immobilization produces excellent results in certain types of fractures, it is appreciated that these requirements are not immediately necessary in all fractures. In

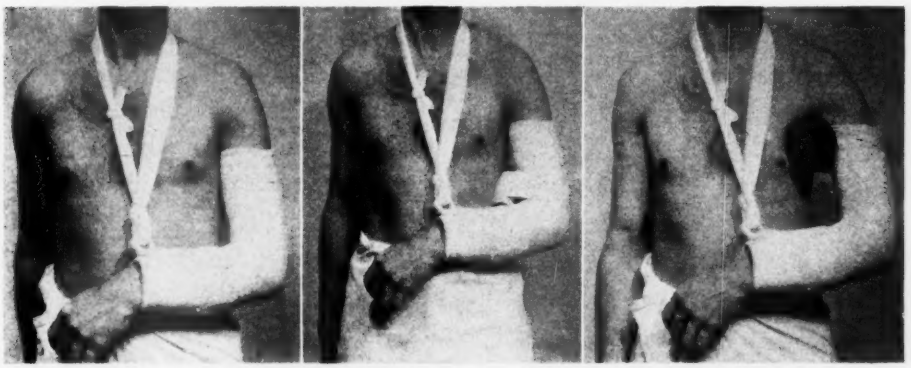


FIG. 1. FIG. 2. FIG. 3.

FIG. 1. "Hanging cast" showing plaster loop at base of thumb, neck sling attached, arm at right angle and wrist and shoulder free.

FIG. 2. Abduction pad placed at bend of elbow.

FIG. 3. Abduction pad placed higher on cast.

treating fractures of the femur, either by the Russell balanced traction method or by skeletal traction, a considerable degree of mobility at the fracture site is expected and regardless of this excellent results are obtained. In addition fixation methods which restrict normal joint function or fix a limb in an unnatural position actually may retard a successful end result. In 1924, Russell[9] describing the balanced traction method of treatment for fractures of the femur, discussed and stressed the importance of applying traction to a fractured extremity which had been so placed that the muscles might assume their normal and accustomed positions. He specifically mentioned the displacement of the fragments of a fractured humerus by the deltoid muscle and stated that it is unnecessary and possibly harmful to seek realignment by the utilization of extreme and unnatural positions of the upper extremity. The normal human carries his arms hanging at the sides of the body; consequently this may be considered as the position of rest. If then, it is possible to treat a fracture with the arms so placed, it is logical to assume that the muscles become relaxed. When this relaxation is augmented by gentle traction, the displaced bone fragments are pushed and pulled into normal relationship.

Since 1935, at Detroit Receiving Hospital, it has been the practice whenever possible to treat all fractures of the shaft and upper third of the humerus in traction by utilizing a light plaster cast in

addition to the weight of the arm. The first series of fifty-eight cases was reported by LaFerte and Rosenbaum.[4] In all there have been approximately 350 cases in this hospital in which this treatment was used. The present report concerns all cases in a two-year period totalling 136 cases. This cast has been described previously by several authors.[2,3,4,5,6,7,8] Suffice it to say that a circular cast is applied to the injured arm covered by stockingette, with the elbow at a right angle. (Fig. 1.) Occasionally, the elbow is placed at a slightly more acute angle to help control anterior angulations in fractures of the lower shaft. The cast extends from just below the axillary folds to the wrist and occasionally the hand is included as far down as the metacarpo-phalangeal joint. A plaster loop, wire or tape is incorporated into the cast at the wrist to which a neck sling is attached. The forearm usually is held in mid-pronation but occasionally the position of extreme pronation or suppination is required. The cast averages two and one-half to three and one-half pounds in weight for an adult. In addition abduction pads may be incorporated into the inner side of the cast to correct angulations. (Figs. 2 and 3.) Anterior or posterior angulation can be corrected by adjusting the length of the sling.

The patient is advised to sleep in a semireclining position for the first few nights and, in addition, is cautioned not to support the cast at the elbow. The time spent by the ordinary ambulatory patient in the erect position affords a sufficient period for effective traction. Although crepitus can be felt by the patient, pain usually disappears after one to three days and the individual soon learns that greater comfort is obtained when the cast is hanging free. After three to seven days active and passive motion is started at the shoulder. This can be instituted by having the patient bend forward and then rotate the arm at the shoulder in ever increasing circles. It is advisable to check the position of the fragments at the end of the first week under fluoroscopic observation with the patient standing. Thereafter the arm should be checked every two weeks. It may be necessary to adjust the sling or to change the size and position of pads on the inner side of the cast during the course of observation. It has been found that this type of treatment can be used in dealing with almost any fracture of the humerus.

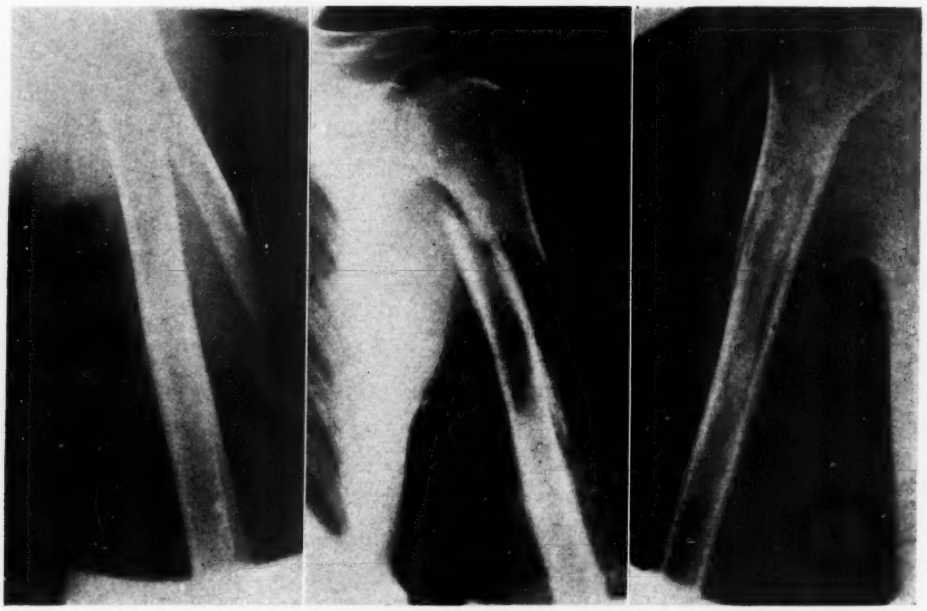
In certain types of fractures of the humerus more or less typical displacements occur, but in the majority the "hanging cast" will correct the deformity or hold alignment after a closed reduction has been performed. It is generally agreed that perfect end-to-end

A B

C

FIG. 4. A, anterior angulation; poor anatomic position; B, fair lateral position; C, perfect function, slight disturbance carrying angle and cosmetic result, two years later.

apposition of the fragments is not necessary for good functional results. (Fig. 4.) The question continually arises as to why internal rotation of the distal fragment in relation to the upper fragment does



A B C

FIG. 5. A, abduction and external rotation upper fragment with shortening and lateral angulation; B, correction lateral angulation and rotation; abduction pad used; C, shortening, angulation and rotation corrected, perfect anatomic and functional result, two and one-half months later.

not occur or persist. Apparently the muscles of the arm and primarily the biceps and the tendon of the long head rotate the upper fragment in the freely movable shoulder joint to correspond with the lower fragment.[10] (Fig. 5.) Fractures in the middle and lower third of the humerus have a tendency to assume a varus position. (Fig. 6.) This can be controlled by inserting a pad on the inner side of the cast at the bend of the elbow and for the lower shaft, by placing the forearm in a position of pronation, for supination increases the deformity as the joint is under the control of the pronators.[5] The great advantage of very free shoulder joint motion cannot be overemphasized and early mobilization can be realized without detriment to the result. The wrist is not included in the cast unless marked pronation is required and practically no stiffness occurs in this joint. In addition the continued use of the muscles of the upper arm and forearm, although limited, is quite considerable and the elbow joint does not seem to stiffen as it often does when placed in a rigid fixation apparatus. Obviously the reduction in the number of stiff or partially

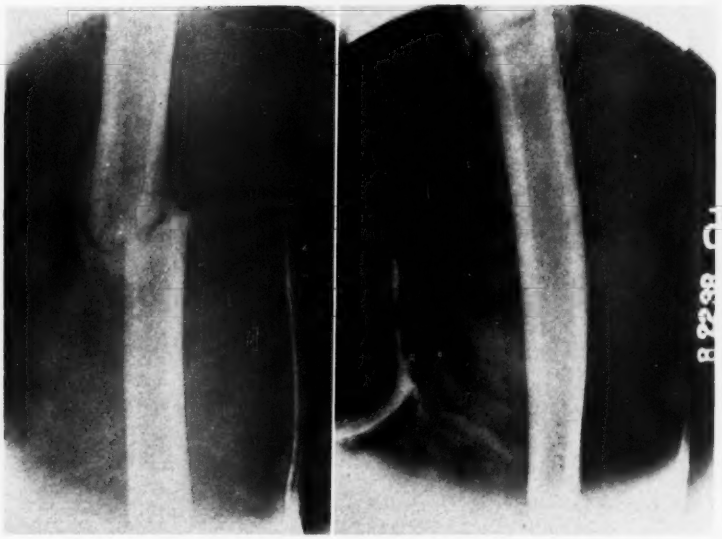
stiff joints is important particularly in the older age groups. The degree of motion permitted by this method keeps the muscles in tone and permits of excellent blood supply, this latter undoubtedly being responsible largely for the reduction in the number of delayed and nonunion cases.

In addition it might be stated that we do not favor its use for true supracondylar fractures with posterior displacement, although we have utilized this method for the flexion type in adults. Griswold[5] has employed this method frequently with great success in this type of fracture. There may be a theoretic objection to the traction cast when dealing with severely comminuted fractures of the head, it having been pointed out that distraction and displacement may occur.[4] This has not been our experience. In badly displaced fractures of the surgical neck and upper one-third of the humerus, one should not expect the "hanging cast" to correct the displacement. Occasionally, however, correction is obtained. It has been our experience that these fractures with marked displacement are difficult to reduce by closed manipulation. Actually amazingly good functional results are obtained although the anatomic position is poor. Emphasis should be placed upon early mobilization and restoration of shoulder function rather than upon obtaining perfect anatomic reposition. Only occasionally does it seem justifiable to resort to open operation, as the results obtained by the "hanging cast" along conservative lines are so excellent.

Early in the use of this method it was our practice to reduce the fragments in shaft fractures by manipulation under anesthesia. This, however, is not now our general course of procedure as it has been found that simple alignment and the immediate application of a traction cast will produce excellent functional and satisfactory anatomic results. Care must be taken not to use too heavy a cast as distraction may be produced and this particularly applies to the transverse shaft fractures. Obviously, if the patient is confined to bed because of associated injuries the hanging cast cannot be used. In addition, we do not favor its use early in compound fractures, although it may be used here as a convalescent splint or as a continuation method of therapy. Theoretically, one might expect difficulty because of lack of co-operation with very young children. Nevertheless, we have not found this to be true, some of our best results having been obtained in children under ten.

The evaluation of the method should be made on the results obtained. The following analysis is based on 103 cases of the 122

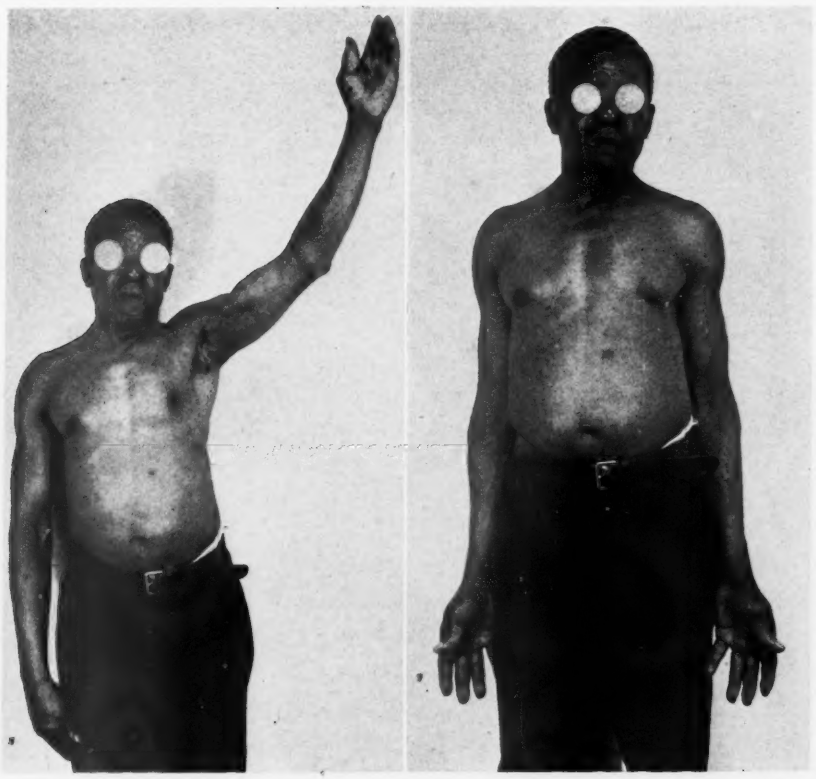
A



B

FIG. 6. For descriptive legend see opposite page.

cases in which the "hanging cast" was used exclusively. We were unable to obtain complete follow-up data on nineteen cases although in several of these progress had been satisfactory. The patients have



C

FIG. 6. A, lateral angulation and slight internal rotation lower fragment; B, good anatomic position; abduction pad used at elbow; C, excellent function; no deformity, two years later.

been seen for their final evaluation in from six weeks to two years after removal of the cast. In determining the final result we have used the qualifying terms, "excellent," "good," "fair," and "poor." By "excellent" we mean that function of the arm has returned essentially to its former normalcy. Perfect anatomic reposition as measured by the *x*-ray, although obtained in a large majority of instances, was not particularly sought after and it should be stated that there was little or no correlation between this and the functional result. Cosmetic results except in a few instances were uniformly excellent.

The lesions were grouped according to this classification: (1) fractures of the upper third of the humerus including the neck in (*a*) initially good or fair, and (*b*) poor position; (2) fractures of the middle

and lower third of the shaft in (*a*) initially good or fair and (*b*) poor position.

It will be seen in referring to Figure 7 that the age incidence was rather widely distributed. Of all of the five-year periods the greatest

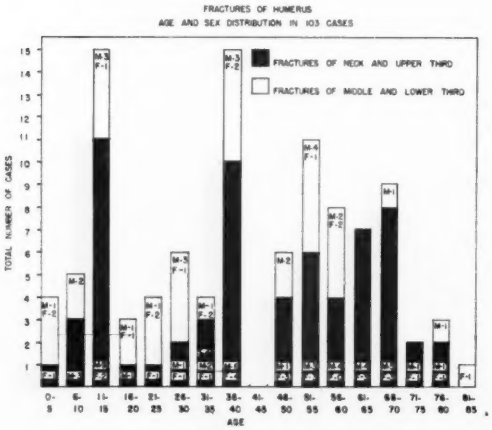

FRACTURES OF HUMERUS
AGE AND SEX DISTRIBUTION IN 103 CASES
FRACTURES OF NECK AND UPPER THIRD
FRACTURES OF MIDDLE AND LOWER THIRD
TOTAL NUMBER OF CASES
AGE

FIG. 7.

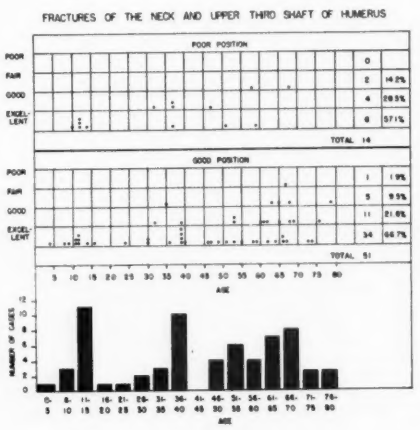



FIG. 8.

number of cases of both types occurred in the periods of eleven to fifteen years and thirty-six to forty years. In general, patients with injuries involving the upper portion of the humerus were slightly older than those suffering from fractures of the more distal shaft. There were more males than females in the series and there was little or no correlation between age and sex. A larger number of fractures occurred in the upper third of the shaft and neck than in the middle and lower one-third of the shaft of the humerus.

The functional results (Fig. 8) in the fractures of the neck and upper one-third of the humerus in initially poor, as well as good position show a tendency to be less satisfactory in the older age groups. Combined "excellent" and "good" results for the poor position group were obtained in 85.6 per cent and for the good position group in 88.3 per cent. In this entire group only one case, a sixty-seven year old female, obtained a "poor" functional result, abduction being limited to 50 degrees.

It is apparent from Figure 9 that the lower humeral fractures occur in a somewhat younger age group. Relatively, the younger age groups with distal shaft fractures received less satisfactory results than the same age groups with upper humeral fractures. More "excellent" results (77.3 per cent) were obtained in the middle and lower one third of the shaft fractures in good initial position than for those in poor position (42.9 per cent). However, the combined

percentage of "excellent" and "good" results was 80.6 per cent for those in good position and 85.8 per cent for those in poor position. In comparison the fractures of the lower humerus seem to produce slightly more disability than those of the upper shaft.

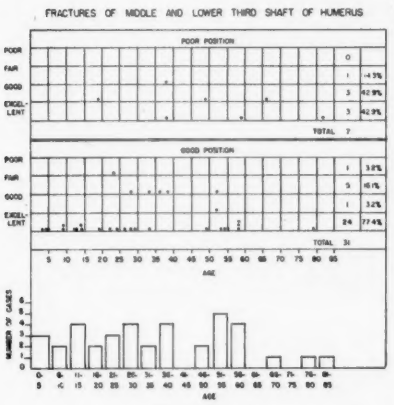



FIG. 9.

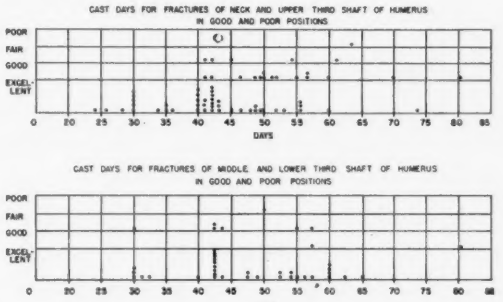

CAST DAYS FOR FRACTURES OF NECK AND UPPER THIRD SHAFT OF HUMERUS IN GOOD AND POOR POSITIONS
CAST DAYS FOR FRACTURES OF MIDDLE AND LOWER THIRD SHAFT OF HUMERUS IN GOOD AND POOR POSITIONS
POOR
FAIR
GOOD
EXCELLENT
DAYS

FIG. 10.

Again it should be pointed out that in this entire group of lower shaft fractures, it was considered that in only one a poor functional result was obtained (85 degrees limitation of shoulder motion, slight restriction of rotation and slight disturbance of carrying angle).

The number of cast days (Fig. 10) varied considerably but it is evident that in the majority removal was effected in the thirty-day to sixty-day period. The average number of cast days for the whole series was 47.5 days and this held essentially for the various types and locations of the fractures. There was little or no correlation between the number of days in the cast either of the age of the patient or end result. It might be stated that the use of the cast for six to nine weeks is slightly longer than that reported by previous authors. We have no definite explanation for this except that of conservatism and also as we believe that the slight prolongation of the time in the hanging cast does not particularly effect a rapid functional recovery.

In the entire group of 103 cases shoulder function was estimated as excellent in sixty-nine cases, good in nineteen cases, fair in thirteen cases and poor in two cases; a combined percentage of excellent and good results of 85.4 per cent. The usual disturbance though slight was mild limitation of abduction and in only three instances was there restriction of rotation.

Function of the elbow joint was but mildly disturbed in five cases, two of these having slight decrease in the carrying angle and one a

slight increase, while of the remaining two cases, one had 10 degrees limitation of extension and one had between 10 and 15 degrees limitation of full flexion. These cases, however, were considered to have "good" function.

Nerve injury occurred in four cases, one median and one radial in the upper humeral fractures and two radials in the lower shaft lesions. Two of these were explored and all had perfect return of function.

There was one case of delayed union. This thirty-eight year old female patient had a severely comminuted, oblique fracture in the supracondylar area and lower one-third of the shaft. Marked varus deformity persisted for several days and there was delay in correcting this by pronation of the forearm.

Although there was sufficient union to remove the cast in sixty days, the degree and solidity was questioned for thirty days more. The general result was excellent, with only a barely perceptible disturbance of the carrying angle.

One nonunion occurred in a fifty-two year old negro female who had sustained a transverse fracture at the junction of the middle and upper one-third of the shaft of the humerus. This patient was an alcoholic in poor general condition. At the end of five months, fibrous union with some evidence of a pseudo-arthrosis was present. The general functional result, however, was fair. Operation was advised but the patient refused, and no further follow-up could be obtained.

Physiotherapy was used in twenty-two cases of the 103.

Closed manipulation under anesthesia was performed in seven cases, only one of these having a lower shaft fracture. However, there were a considerable number of cases in which simple alignment of the fragments was carried out without anesthesia. Open reduction was resorted to in one case immediately and postoperative treatment by "hanging cast" traction produced an excellent result.

It was necessary to hospitalize twenty-one cases for periods varying from one to sixteen days, thirteen of these patients remaining in the hospital under six days. Of the twenty-one cases, thirteen required hospitalization because of associated injuries and eight were observed for a short period because of the degree of trauma to the soft tissues of the arm.

In addition to the 103 cases in which the "hanging cast" was used exclusively as the treatment of choice, there was a group of fourteen cases in which the traction cast together with other types of traction and fixation was utilized. These cases were not included in

the complete analysis as it was impossible to evaluate accurately, the importance of any one method. Six of these cases were compound fractures which were initially treated by operative procedures; skeletal and other forms of traction. The "hanging cast" was applied as a continuation or convalescent splint in from four days to six weeks after the primary treatment. All of these patients obtained satisfactory results.

The remaining eight cases were hospitalized because of associated skeletal or soft tissue injuries and were first treated by other traction methods, the "hanging cast" being used six to twenty-four days later to supplement the therapy. These individuals also received satisfactory results.

These latter cases emphasize the value of the "hanging cast" as a method of adjunct or convalescent treatment.

## SUMMARY

1. The method does not depart from established principles as widely as is generally supposed.

2. It is applicable to most fractures of the humerus.

3. It is cheap, simple and easy to apply.

4. It is comfortable.

5. The method permits the patient to be ambulatory and allows early mobilization of joints.

6. The number of hospital days and the amount of physiotherapy are reduced to a minimum.

7. The incidence of delayed and nonunion is very low.

8. The end results, particularly as to function, are equal to or better than those obtained by other methods.

In conclusion, we believe that the "hanging cast" method of treatment for fractures of the humerus is most effective and should be given a prominent position in the list of the various forms of therapy utilized for these lesions.

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## DISCUSSION

A. D. LaFerté (Detroit, Mich.): In continuing for a moment this discussion, there are just one or two things I should like to add to what Dr. Winfield has said.

We started the use of the hanging cast in 1935 because of the fact that the patients we were treating were having such disability in the shoulder joint, such great muscle atrophy.

I was impressed on being called to see one big, husky athlete who had had a fracture and been put in one of these stock abduction splints. He had an anterior angulation, and he had such atrophy of the shoulder muscles of that side that we suspected a dislocation. The head of the bone stood out; you could pick it right up, while the opposite shoulder was very powerful.

In our meetings at Receiving Hospital on fracture discussion, we decided to try other methods, which we did. We found that this cast was giving us the best result, so from then on we have used this hanging cast a great deal.

One other thing I should like to bring out in the care of these patients, is that in these fractures of the lower and middle third, it might be well not to run the cast up quite to the axilla, because very often the lower fragment will be anteriorly displaced, and if in attempting to displace it posteriorly the cast runs too high, we merely push the upper fragment back instead of controlling the lower fragment.

In some of those fractures, if you want to get a very good reduction at the time with the fracture in complete alignment, run the cast only to the fracture line, so that in tightening the sling you can tilt it backward to control it.

The only thing original, possibly, that we have done is the addition of the pad up here in the barrel-chested man or in the woman with large breasts, in which the arm hangs over the fracture and gives you an external angulation. We put the wedge down here. Occasionally, with the opposite displacement, it is well to put the pad up and let the arm hang over the pad.

I should say that we have been greatly pleased, as we have shown, with the results. Since November 23, 1935, to February 21, 1941, in the Bone and Joint Department alone, some of which cases are included here, we have had 252 cases which we have followed, and among those have had no nonunions.

R. Arnold Griswold (Louisville, Ky.): As Dr. Winfield said, this is a method which, when you consider it superficially, breaks some of the rules of fracture treatment. It does not fix the joint proximal to the fracture, but it works, and comparison with traction suspension treatment of the lower extremity shows why it works. We have now used this method in a series of

almost 500 fractures of the humerus, of which we have follow-up figures on 425.

Fractures above the pectoralis must be reduced. The cast will not reduce fractures of the surgical neck and head. We use Gordon Morrison and Cotton's maneuver for the reduction, and hold the fracture with the hanging cast.

In the shaft, most fractures do not need reduction. However, there will be a percentage that will need manipulation and a small percentage in which soft tissue is interposed and in which operation must be carried out to remove the soft tissue from between the fragments. These may then be treated in the hanging cast with or without internal fixation at the site of fracture.

In fractures low in the shaft and the supracondylar region, we are likely to get deformity. When we break the shaft of the humerus, we loose the supinating effect of the biceps. The elbow joint comes under the control of the pronators which are by far the strongest muscles. When we attempt to supinate the elbow joint or put it in midpronation, it supinates not at the elbow but at the fracture site, and we get a varus deformity.

The varus deformity in lower shaft fractures is the result of supination at the fracture site instead of at the elbow, because the elbow is to all intents and purposes fixed in pronation; so that if the fracture is low in the shaft, the forearm should be put in full pronation in order to avoid this varus deformity.

With full pronation I do not think we need the wedge to get rid of this varus deformity. However, the wedge is a very handy thing in the barrell-chested individual or the woman with large breasts in whom the humerus cannot naturally hang in a vertical position.

We use this cast in almost all cases of fractures of the humerus, except extension fractures in children. We use it in extension fractures in adults and in T and Y fractures in adults if the displacement is not great.

So far we have used it above the insertion of the pectoralis in 191 cases. Of that series we had good *x*-ray and functional results in 113, fair in fifty-six, and poor in four. Of these four, three had stiff shoulders and one had a rupture of the long head of the biceps which was sutured and resulted in poor function.

In the shaft we have treated a total of 180 fractures. We had good *x*-ray and function in ninety-one, fair *x*-ray and function in forty-seven, and poor in eight. Of these eight, three had joint disabilities, two had osteomylitis following compound fractures, and there were three nonunions in the 180 fractures of the shaft.

For fractures involving the elbow, there were fifty-four in all, with good *x*-ray and function, twenty-three, fair, seventeen, and poor four. Those four cases of poor function were traffic elbow fractures which resulted in more or less complete ankylosis.

We believe that the use of this method has simplified to a great extent what used to be a very difficult fracture. Those of you who have old surgical textbooks published prior to 1900 have seen the picture of a man with a sling at his wrist, a co-aptation splint on his arm, and a bag of sand on his elbow. This is the same method of treatment and it still works.

JOHN PAUL NORTH (Philadelphia, Pa.): We have had our interest particularly directed during the use of this method to the question of union, because the shaft of the humerus is one of the familiar sites for delays in union, and because the lack of complete immobilization of a fracture is so commonly cited as one of the causes of delay in union.

Our routine use of the method has been limited to fractures below the surgical neck and above the supracondylar level, using other methods for the fractures at the ends of the bone. We have a small series of thirty-one fractures of the shaft. That is the portion of the bone where one might expect delay in union. Of the thirty-one, eighteen have shown firm clinical union before the end of six weeks. The remainder have been solid within eight weeks, with two exceptions.

One of these exceptions was a virtually bed-fast woman of seventy-eight, with a fracture in the lower third of her humeral shaft, who still at the end of thirteen weeks has only fibrous union. The other, a man of eighty-six with a fracture of the middle third, was an obvious candidate for open reduction because he had muscle interposed between the fragments, but his age and enfeebled condition contraindicated any operation. He died at the end of twelve weeks with his fracture ununited.

Dr. Winfield has mentioned the fact that this method is not applicable to patients in bed. That is true in a sense, because the traction principle does not operate. However, the elderly patients who have to be confined to bed for one reason or another present a serious problem in finding any method of treatment which is applicable, and we have used the method in a group of eight patients who have been in bed for a large part of their early convalescence. The anatomical results have not been as satisfactory as in the patients who are ambulatory. The functional results have been good in the great majority of cases. The two patients I mentioned who had delay in union were in this bed-recumbent group of patients.

One patient was a maniac in the psychopathic division who defied all treatment. She was wildly active. We put on a hanging cast because we did not know any other way of treating her. She tore off the first cast. We put on a second and she chewed that off, and finally we got one on which stayed. I have a film of her arm at the end of four weeks.

This illustration shows the amount of callus which she has put out. I show her not as a good anatomical result, but I do not think such could have been secured by any method. This was in point of fact a swinging cast rather than a hanging cast, because most of the time she had her hand above her head, waving it in the air. It shows that incomplete immobilization in

this case certainly did not interfere with union but produced excess callus with a solid fracture at the end of four weeks.

I would sound a warning about the use of too heavy a cast. We had a young girl on whom a rather heavy cast was applied, and although it did not bring about correction of the shortening at the fracture site, it did produce a temporary subluxation of the shoulder joint.

ISIDORE COHN (New Orleans, La.): They say that a difference of opinion is the reason we still have horse racing in Kentucky.

I first saw Dr. North present this method in Philadelphia a few years ago. I was struck by the good results which he showed, but to my way of thinking, it still violated some of the fundamental principles that I have understood with regard to fractures. In the first place, Dr. Winfield said this is a form of balanced traction. The only thing that I can see that it balances is the shortening effect of the biceps and triceps, but it does not have any effect on the pectoralis major or the external rotators.

We have talked about immobilizing fractures in other places; why not have fixation of fractures of the humerus? You certainly have no fixation here. We saw some pictures up there with a lot of callus around. Why that does not involve some of the nerves in the arm is beyond me, that's all. Without balanced traction, without fixation at the site of the fractures, a lot of the things we have said and taught about fractures have just got to go by the board.

Another thing, it is perfectly evident to me that this method does permit unopposed rotation of the shaft and can result in an axial rotation of the limb.

I believe in the abduction type of dressing, which we have been using now for close to thirty years, with fixation of the elbow and the shoulder, and sufficient external rotation to overcome the internal rotation of the pectoralis major is of importance. And while I cannot present 500 cases in one instance and 250 in another, smaller series carefully observed by individuals are of as much importance as large series presented, even though one is overwhelmed by statistical compilations.

Personally, I believe that the old principle of fixation of the site of the fracture, taking into consideration all of the anatomical principles, is of importance; and certainly if one is going to use traction, it ought to be balanced traction, that is, traction taking into consideration all of the elements which may have to do with the fracture.

ROBERT H. KENNEDY (New York City): I wonder if I may ask a question of Dr. Winfield, Dr. Cohn and Dr. North. I would like to ask whether they are teaching this method to medical students at the present time as the method of choice in these fractures.

DONALD GORDON (New York City): I have never used this method. I have been very antagonistic toward it, but I am profoundly impressed

with the results shown here, both in numbers and in the results from its use in different parts of the country.

I had the opportunity of discussing this method in Philadelphia two

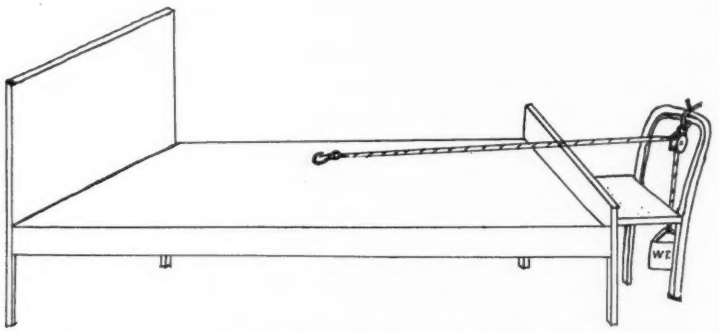

FIG. 11. Arrangement for traction at night for hanging cast.

years ago. At that time Dr. Hubley-Owen submitted a paper and admitted two violations of surgical principles. If we are told, as Dr. Cohn has brought out, to adhere to surgical principles, it seems to me that we should not depart from them. Although I have had no experience in this particular method, I have always treated my fractures of the humerus, that is, ambulatory cases, by a method which is a modification of the old Hamilton traction, namely, the narrow sling, the weight as suggested, and if needed, co-aptation splints.

I have found that in ambulatory traction of that type, as I interpret this hanging cast, it is an ambulatory traction, using gravity and the weight of the cast to afford traction, with a narrow sling or the equivalent of a narrow sling supporting the wrist. I have found that these patients, when they went to bed, in order to have the action of gravity maintained, needed a traction cord hooked to the traction spreader and carried through a pulley tied to a chair at the foot of the bed. The way I make use of gravity, I would suggest, can be made use of in the hanging casts.

Patients in bed or who are hospitalized, can be made more comfortable, I am sure, and the reason I seek comfort for the patient in a case of that sort, is that I do not want to be disturbed myself at night. The method I have adopted is to use traction at night as well as in the day time. The traction weight that I have used in the day time for the ambulatory patient, is proportionate to the musculature of the individual, and is buttoned to the traction straps attached to the arm. At night, that weight is unbuttoned and a spreader with a little ring on it is applied, a traction cord is hooked to this ring, the other end is passed through the pulley on the chair at the foot of the bed and is tied to a weight. I instruct the patient how to arrange that chair with the seat toward the bed, so that the weight will hang free. I tell them to snap the rope with a little snap into the wire ring. (Fig. 11.)

That, in conjunction with an axillary pad and swathe relatively immobilizes that arm, gives the patient comfort, and I obtain the objective which I am after not to be disturbed at night.

For patients who are not ambulatory and who are in bed, I would make this suggestion, to have a little wire loop attached to the elbow portion of the cast so that the night traction can be hooked into it. A number of cases may not require it, but in those that do, I think it will work.

LAURIE H. MCKIM (Montreal, Canada): I would like to say a good word for the hanging cast as applied to the fractures of the shaft, and I specifically make that statement.

Dr. Gordon has just covered one of the points I intended to bring forth. I will refer to that in just one moment. The hanging cast is really nothing more or less than a modification of the Jones' humerus extension splint which I am surprised to find so few men have learned to use. That splint, as you will remember, was the double bar with a ring around the shoulder, and parallel bars for the forearm in which the forearm was suspended. The degree of extension that was obtained was graduated by the point at which the sling for the wrist was attached to the bar.

The nearer it was attached toward the end of the fingers, the greater degree of extension was obtained. If too much was obtained, the sling was brought back nearer the elbow.

I have used this hanging cast for a number of years with the single modification that I have attached a number of rings to the cast, so that the amount of extension that I obtained could be graduated.

The other point I was going to bring forth, just brought out by Dr. Gordon, is that it can be applied to patients in bed, and I think it is a very distinct advantage to incorporate two small rings, one at the wrist and one at the elbow. Put a Balkan frame over the patient's bed, and when the patient goes to bed at night two hooks are attached with weights over pulleys, one to the elbow and one to the wrist.

During the night the arm hangs in this position in bed. It prevents swelling of the arm, you get rid of a great deal of edema that occurs during the day, and the following morning the patient can get up and attach the sling to the wrist and walk about during the day.

I wish particularly to refer again to the fact that graduated extension may be obtained and overextension, which sometimes occurs, may be prevented by attaching the wrist sling to the various points on the forearm.

CLAY RAY MURRAY (New York City): I would like to comment on this method of treatment, primarily from the basis of the series of cases presented here, and numerous other series which I have seen all over this country—evidently an example of a fracture getting well despite treatment.

The reason I emphasize this is because of the remarks which Dr. Cohn made. Dr. Cohn said as a result of seeing this series of cases, that all our principles of fracture treatment had to go by the board. That is the phase of the story on which I should like to comment.

I do not believe that is so. Because we have a series of cases which get well despite the violation of every principle known to fracture treatment is no reason why one should assume that, therefore, in all other fractures, we can do the same thing.

I think the principles of fracture treatment have to stand, despite the success of this method of treatment. There is no question about its success. I think the percentage of fair results is a good deal higher than is commonly found. I think Dr. Griswold's statistics brought that out in the "fair" results.

I think there is a language difficulty in the use of the word "fair," but his percentage of fair results was reasonably high, and fair results in fractures of the upper end of the humerus are unusual. Fair results should be a small number cases.

One might argue on the same basis if one were to say that this proves that the ordinary principles of fracture treatment should not be so rigidly observed, that necks of the femur should be treated in the same way that intertrochanteric fractures are treated. I think that would be a difficult thesis to uphold.

The fact that by apparently violating all principles of fracture treatment in the use of this method one can get good results in fractures of the shaft of the humerus, is no reason for trying a hanging cast or a pseudo-hanging cast to a tibia or a femur or both bones of the forearm. I think the apparent violation of principles, which is successful, should be distinctly limited to the humerus, and we should try to find the answer to the unquestioned riddle presented by the success of the method.

HENRY C. MARBLE (Boston, Mass.): I think this is developing into a little bit of a diehard of the ancients, who are dying hard on the violation of principles.

About 1924, or thereabouts, I presented at the American Medical Association a report of some cases in which we treated fractures of the surgical neck of the humerus by violating every principle of surgical treatment, and just letting them swing a flatiron. It hurt my surgical sensibilities terribly to do it, and the unfortunate part of it was that the patients got well with good results.

Apparently the upper half of the humerus is something which particularly admits of violation of surgical principles. My surgical sensibilities are shocked just as badly as Dr. Cohn's and Dr. Murray's. But maybe it is not all true; maybe it is not such a violent violation. Perhaps if we thought it over for a long while and got to the point where we do not put any cast or any splint on at all (if we must be medical purists, because this is not a cast), but put on a plaster splint and then reduced the plaster splint to nothing, and then perhaps if we just put a little piece of lead in the man's elbow, as in Scudder's first edition many years ago, we may get the very same results.

Maybe we are calling this the wrong thing. I do not think the application of the plaster splint does much to the patient. Maybe if you put a tiny weight at the elbow or on the bag, such as Dr. Griswold mentioned, we would get the same results. Surely the upper half of the humerus does do well, as Dr. Murray says, regardless of what we do to it, as long as we have motion.

This is not so bad a violation, because we do have motion. We keep the muscles in tone; we let the shoulder move. We violate another principle and let the wrist fall in the flexed position, but apparently they do perfectly well. Maybe in the future if we just take off the plaster entirely and put on a little lead foil over the elbow to do the same thing as this does, with still more violation, we will get just as good results.

The fact remains that here we have before us Dr. Griswold and Dr. Winfield and Dr. North. I have seen their cases, and they have perfect results. Why they do not all have radial paralysis, as so many of our patients do have, I do not understand. They have enough callus there because of motion; there is no radial paralysis; everything is wrong, yet the end result is good.

I never have used a hanging cast; I never could quite bring myself to it, but I have a feeling I shall now go home and swallow my surgical sensibilities and use the hanging cast because I think it is a swell thing.

CARLETON MATHEWSON, JR. (San Francisco, Calif.): I cannot understand why nothing has been said about distraction. In my experience, the most common site of nonunion and delayed union is in transverse fractures of the lower third of the humerus. We have attributed this to distraction.

In all of the cases of nonunion in the lower third of the humerus that I have reviewed, I have found that there was distraction present sometime during the period of treatment. Possibly the people in this part of the country are more muscular than our own and distraction does not occur. We have found in old, debilitated people that the weight of the forearm alone in the right position is enough to distract the fragments. If you maintain distraction during the period of treatment, nonunion will occur.

We have found it necessary in these cases, particularly in debilitated people, not to put traction on the arm but to attempt to force the fragments into approximation with one another.

PAUL B. MAGNUSON (Chicago, Ill.): I do not like to continue this when there is so much discussion that has preceded it, but I remember a number of years ago I came to Montreal and saw a pillow used for a splint by our President, Dr. Gurd, on fractures around the ankle, the lower end of both bones of the leg. I have found that that same pillow works very well as a splint for the humerus, especially in old people, if you put it on correctly.

Dr. Gurd called attention to the fact that a pillow should be pinned around by the pillow case and not the pillow. If you slip a pillow under the arm on these old people who are in bed, pin the top around the shoulder to

the one side, pin the pillow case around the arm and put the arm in a sling, these patients can get up or lie down. The pillow, if it is of the proper quality, that is, nice and soft and not too thin, will wad up and give just enough countertraction to make the arm perfectly comfortable.

It seems to me the muscles of the upper arm are entirely different in strength, in enervation and irritability than any other muscles that control the long bones.

Dr. Marble showed this perfectly, I think, in his treatment of swinging a flatiron for fractures around the shoulder many years ago, and I sat in the balcony the day he did it. I did not know him as well then; I could not call him a "nut," but that is what I thought.

But I went home and managed to put my surgical sensibilities where he says he is going to put his, and started to treat these fractures this way and got fine results. I came in the other day and found a patient of mine with a fractured humerus lying with the shoulder and the elbow on the bed, and complaining of pain. The answer was there was no support to take off the cross-strain. As soon as the pillow was put upright, with support from the shoulder to the elbow, the pain disappeared. The next day, as I had her lean over and begin exercising her shoulder with the pillow, holding the end of the fingers with the pillow, she was perfectly comfortable.

That has been my experience with fractures of the humerus. They do not need pull; all they need is support. If you can get these patients to relax their shoulders while they are upright, and let the arm hang, they do not have pain; there apparently is not any tendency to displacement; and if you will give them support between the shoulder and elbow with a mild support of the pillow traction between the axilla and the flexed elbow, they seem to do perfectly fine.

I quit worrying about them now since I have not put so much apparatus on to pull and push them.

Fraser B. Gurd (Montreal, Canada): I would like to use one minute to point out that the humerus at the glenohumeral joint is the only joint in the body that is supported in the way in which it is, namely, with the long head of the biceps running through what is substantially a tunnel in the bone, and that the safety of a procedure such as described by Dr. Winfield and the other contributors this morning is dependent upon that cable-like support transmitted to the fracture line anywhere in the upper two-thirds of the humerus, or even down to the ultimate and penultimate fifths of the bone when the long head of the biceps is put under strain.

James M. Winfield (closing): I would like to answer some of these questions, if I may.

I agree entirely with Dr. Gurd about the tendon of the long head of the biceps, helping to correct angulation and rotation. I can only say to Dr. Cohn that we do not believe the method of treatment violates surgical principles.

As far as Dr. North's experience with union is concerned, our results parallel his quite closely.

To Dr. Kennedy's question: Yes, we do teach this method to our students.

It seems to me that Dr. Gordon's method of treating the ambulatory patient is very much like ours. I agree with him about placing a hoop at the end of the cast, at the elbow, and we have utilized this in casts for individuals who have been confined to bed for a short period of time, although we do not believe that for prolonged bed treatment the hanging cast is particularly efficacious.

We did change the rings at the distal end of the cast, as Dr. McKim pointed out, not only distally and proximally, but also to increase and decrease rotation of the forearm.

Dr. Mathewson brought out distraction. I think it is a very important point.

I know Dr. Griswold has used light sugar tongs with some of these individuals instead of the cast. At times, the cast must be light, two or three pounds may be too heavy. This applies particularly to the transverse shaft fractures.

I think that is all I have to say, except that I should like to thank everyone for this very interesting discussion.

# INJURIES TO THE ACROMIOCLAVICULAR JOINT*

## A PLEA FOR CONSERVATIVE TREATMENT

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OF the shoulder injuries occurring in individuals competing in body-contact sports, none are more common than those involving the acromioclavicular joint. Football, lacrosse, soccer, rugby and hockey are the sports in which such injuries are usually produced. The functional anatomy of this particular joint, the mechanism of injury, and a review of 173 cases are included in this study, together with a discussion of treatment. Admittedly, it is fortunate that a surgeon is present when these injuries occur; a diagnosis is made and prompt measures instituted for immediate treatment.

In view of a recent trend toward rigid fixation of injured acromioclavicular joints with pins and even screws, it seemed of interest to report the results of a large series of cases in which the patients were treated conservatively. Rigid fixation of this joint is not logical anatomically. Gray[1] states, "The movements of this articulation are of two kinds: (1) A gliding motion of the articular end of the clavicle on the acromion. (2) Rotation of the scapula forward and backward upon the clavicle, the extent of this rotation being limited by the two portions of the coraco-clavicular ligament. The acromioclavicular joint has important functions in the movements of the upper extremity. It has been well pointed out by Sir George Humphry that if there had been no joint between the clavicle and scapula the circular movement of the scapula on the ribs (as in throwing both shoulders backward or forward) would have been attended with a greater alteration in the direction of the shoulder than is consistent with the free use of the arm in such position, and it would have been impossible to give a blow straight forward with the full force of the arm; that is to say with the combined force of the scapula, arm, and forearm." According to Mollier,[2] the range of motion is approximately thirty in the coronal axis, fifteen in the vertical, and about twenty degrees

* From the Department of Hygiene, Harvard College, and the Department of Surgery, Harvard Medical School.

in the sagittal. Obviously, rigid internal fixation of this joint would seriously impair motion of the shoulder.

A review of the anatomy of this joint and the mechanism produc-

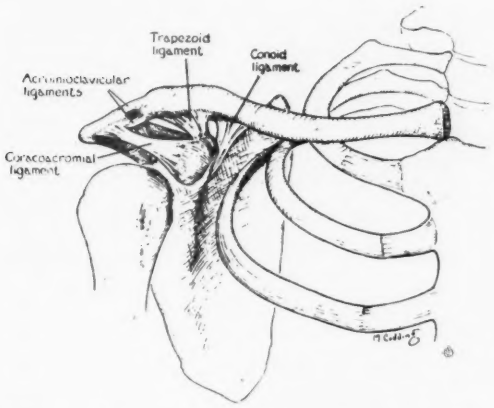


FIG. 1. Diagram of the ligamentous attachments between the clavicle and the scapula.

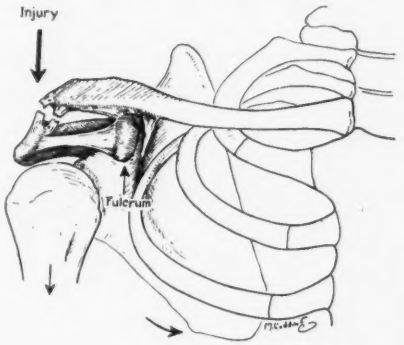


FIG. 2. Diagram showing the effect of a blow on the anterior or superior aspect of the shoulder beyond the end of the clavicle.

ing this injury seems appropriate. The joint consists of a rather weak capsule reinforced by five ligaments: the superior and inferior acromioclaviculars, the conoid and trapezoid coracoclaviculars, and the coracoacromial. (Fig. 1.) The articular surface of the clavicle lies on the acromion facing downward, outward and backward. This anatomic arrangement makes posterior or downward displacement of the clavicle almost impossible and such an injury is in fact a clinical rarity. However, upward dislocation of the clavicle, or perhaps more properly, downward displacement of the acromion, is common. The mechanism of this injury was first thoroughly studied by Porier and Rieffel[3] in 1891. These authors demonstrated that force applied to the anterosuperior aspect of the shoulder beyond the end of the clavicle causes the scapula to rotate so that the coracoid process becomes the fulcrum of a lever, the end of which is the acromion. (Fig. 2.) The superior and inferior acromioclavicular ligaments are the weakest points in the lever arm and give way easily, producing a partial dislocation of the joint. If the force is continued, the whole scapula is also depressed or rotated, the first rib becomes the fulcrum, and the much stronger conoid, trapezoid and coracoacromial ligaments may be injured, thus producing varying degrees of complete dislocation. (Fig. 3.) Partial separation is in our experience much more common than complete. As Cadenat[4] has

shown, the clavicle itself may well give way before the conoid, trapezoid and coracoacromial ligaments are affected.

Force applied from below, for example, from a fall or blow on the

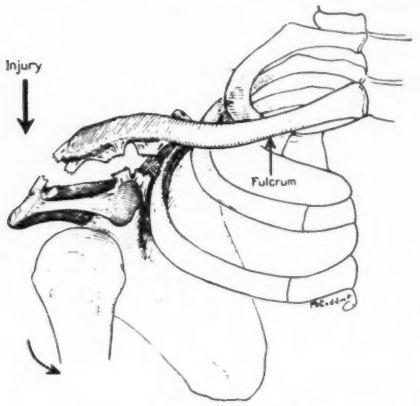


FIG. 3. Diagram showing the effect of a severe blow on the anterior or superior aspect of the shoulder lateral to the acromioclavicular joint.

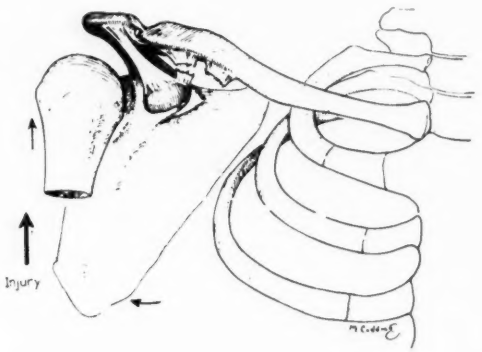


FIG. 4. Diagram showing the effect of a blow transmitted from below through the humerus.

elbow and transmitted through the humerus, is a less common cause of injury to the acromioclavicular joint, but one that we have occasionally encountered. In this case, the scapula rotates on the acromioclavicular joint itself. The joint suffers more contusion than dislocation, and occasionally the conoid and trapezoid ligaments may be severely damaged. The medial end of the clavicle is held down by the strong costoclavicular ligaments. (Fig. 4.)

As a rule, there is little difficulty in establishing the diagnosis. Immediately after the injury the patient complains of pain about the whole shoulder, not necessarily localized at the acromioclavicular joint, loss of function and weakness of the arm. The acromioclavicular joint, and more particularly the clavicle and its articulation, supports the entire shoulder girdle. Occasionally, there is numbness, tingling or even transitory paralysis of the arm, the probable result of compression of the brachial plexus between the clavicle and the first rib. This symptom was present in four or 2.3 per cent of our 173 cases, in none of which could any subjective or objective evidence of nerve damage be demonstrated after a brief transitory period.

Examination reveals a considerable loss of function, of flexion, extension, abduction and adduction, together with tenderness directly over the joint, but often extending out over the deltoid and trapezius muscles. In cases in which the trauma has produced separation, increased mobility of the clavicle on the acromion can invari-

ably be demonstrated. Downward pressure or percussion on the medial third of the clavicle almost always elicits pain at the lateral end. The degree of separation is usually slight, but occasionally will produce complete dislocation, causing the clavicle itself to rest on the superior surface of the acromion.

The *x*-ray is of value principally in ruling out associated fracture. *X*-ray films were taken seventy-two times in our series of 173 cases, but minor displacement at the joint was demonstrated only eight times. Diagnosis of these displacements by *x*-ray films is not accurate and the *x*-ray should be resorted to only to prove the possibility of accompanying fractures at the margins of the joint. We have found in this series no marginal fractures of the clavicle, but one of the acromion. King and Holmes[5] have recommended an *x*-ray technic for proving the separation, but even this is fallible in the hands of most technicians. (Table 1.)

TABLE 1
ACROMIOCLAVICULAR INJURIES ALL SPORTS

| Academic Year | Contusions | Sprains | Separations | Total |
|---|---|---|---|---|
| 1934 to 1935 | 7 | 0 | 23 | 30 |
| 1935 to 1936 | 3 | 0 | 33 | 36 |
| 1936 to 1937 | 7 | 1 | 23 | 31 |
| 1937 to 1938 | 1 | 2 | 22*† | 25 |
| 1938 to 1939 | 3 | 3 | 15 | 21 |
| 1939 to 1940 | 3 | 5 | 22 | 30 |
| Total | 24 | 11 | 138 | 173 |

* One case complicated by a fracture of acromion.
† One case of complete dislocation.

A variety of plans of treatment have been proposed. A number of operations have been devised, which fall into two general types: variations of the reefing operation, first described by Cadenat,[4] which lashes the clavicle to the acromion by fascial, silk or wire sutures, and operations designed to fix the joint with screws, wires or pegs. In none of our cases was operation necessary, although three presented marked displacement. For the rare case in which conservative treatment fails, we agree with Liberson[6] that careful reinforcement of the conoid and trapezoid ligaments is preferable to fixation of the joint. In this series we report operation was never resorted to.

The late Willis Campbell,[7] with whom we disagree, was of the opinion that "no form of conservative treatment is of any value,"

and advocates abduction in plaster of Paris for six weeks and operation for those with marked displacement. Codman,[8] on the other hand, states that he has "never found it necessary to operate on acromioclavicular dislocation."

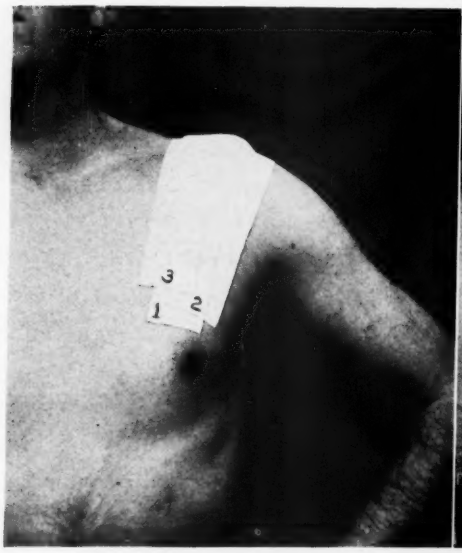


FIG. 5. Adhesive tape fixation of separation of the acromioclavicular joint.

FIG. 6. Protective taping used after injury to the acromioclavicular joint.

The many conservative strappings which have been described by Eliason,[9] Howard,[10] Wilson and Cochrane,[11] and others, are in general modifications or refinements of the brachioclavicular sling of Sir Robert Jones,[12] the principle of which is elevation of the humerus and depression of the clavicle. In our experience, elevation of the humerus is unnecessary and adequate fixation can be obtained by simple adhesive strapping across the joint from the lower angle of the scapula posteriorly and carried over the joint and down on to the anterior thorax. (Fig. 5.) A small felt pad is fixed across the joint by the tape. This method of external fixation we recommend for immediate treatment, and in the more severe cases we occasionally use a triangular sling for a few days.

During the years 1934 to 1940, strapping of this type was applied to 138 separations of the acromioclavicular joint occurring in college men participating in athletics. In every case, treatment was instituted immediately after the injury. For the first few days treatment was directed as much to the associated contusion as to the dislocation, but the joint was immediately fixed with adhesive tape as soon as the diagnosis was confirmed by the demonstration of increased

mobility. The strapping should be removed after forty-eight hours, high frequency diathermy applied for twenty minutes, followed by gently stroking massage and the strapping reapplied. This is repeated every second day for a total of eight days from the injury or until the shoulder function is tested for abduction, flexion, extension and horizontal abduction and, compared with the normal shoulder, reveals the return to normal. Not until normal function returns do we permit return to contact sport and only then with the protection of supportive adhesive strapping (Fig. 6) and special pads. The average period of disability for this series of separations was 10.5 days for all these types of injuries. The left acromioclavicular joint was involved eighty-one times, and the right fifty-seven times. As might be expected, football produced the greatest number of injuries, 106; rugby thirteen; hockey eleven; lacrosse six, and track two. In two cases, in addition to the usual treatment, the joint was infiltrated with novocain without benefit. (Table II.)

TABLE II
PERIOD OF DISABILITY
Injuries to the Acromioclavicular Joint

| Contusions | | Sprains | | Separations | |
|---|---|---|---|---|---|
| No. of Cases | Days | No. of Cases | Days | No. of Cases | Days |
| 24 | 9.2 | 11 | 6.1 | 138 | 10.5 |

Average disability for the 173 cases was 8.9 days.

The one case in the series which we did not have an opportunity to treat immediately after the injury is of sufficient interest to merit a detailed report:

CASE REPORT

W. B. consulted one of us (A. T., Jr.) sixteen days after sustaining an injury to the right shoulder in a semiprofessional football game. An *x*-ray had been taken elsewhere and cold applications had been prescribed. After a week of marked discomfort, an osteopath was consulted who strapped the shoulder. Pain and discomfort continued despite the strapping which was removed by the patient after another week.

Upon examination there was found a typical severe dislocation of the right acromioclavicular joint. The clavicle lay on the top of the acromion.

The dislocation was easily reduced without an anesthetic and held with strapping across the joint. (Fig. 6.) Immediately after the strapping was applied the patient stated that he was comfortable for the first time since

the occurrence of the injury, sixteen days before. *X*-rays taken before and after reduction and taping showed normal realignment of the gross displacement of the bones. (Figs. 7 and 8.)

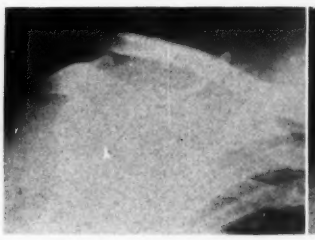

FIG. 7. FIG. 8. FIG. 9.

FIG. 7. Case W. B. Dislocation of the clavicle on the acromion for sixteen days.
FIG. 8. Case W. B. After reduction.
FIG. 9. Aseptic necrosis.

Three weeks later the strapping was removed and displacement did not recur. Three and one-half weeks later he resumed football as a blocking back, with protective strapping to the joint. He has played through two seasons since without trouble from the shoulder.

The sprains of the joint are minor degrees of the same type of injury and are treated in much the same way. Contusions involve not only the joint, but the marginal muscle attachments at the joint, the deltoid and the trapezius. The restoration of full function in these latter occasionally prolongs the disability period. Treatment involves reduction of the hematoma and hastening of its absorption by immediate cold applications and compression bandage and later heat and massage.

*Complications.* Among the complicating factors of injuries to the acromioclavicular joint are: (1) Marginal fractures involving the acromion or clavicle; (2) contusion with transient palsy of the brachial plexus; (3) an interesting type of bone lesion seen only in protracted cases and having the *x*-ray appearance of aseptic necrosis adjacent to the joint surfaces. Of these latter complications we have seen two. (Fig. 9.) At the margins of the joint there are punched out areas of rarifaction. Tenderness persists as a rule for at least three weeks and disappears as the *x*-ray appearance of the bone returns to normal. The lesion is obscure but of general interest.

## SUMMARY

1. The functional anatomy and the mechanism of injury to the acromioclavicular joint is discussed.

2. A simple conservative method of treatment is described, together with the result of its application in 173 consecutive cases.

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## DISCUSSION

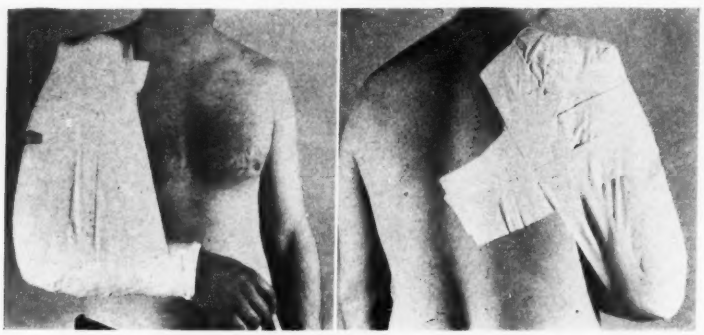
James M. Winfield (Detroit, Mich.): It is a pleasure to discuss Dr. Thorndike's excellent paper. In recent years there have been a considerable number of articles dealing with this subject. I might say that they can be divided into those preferring early operation, the nonoperative conservative group, then the group that tries conservatism and operation, if necessary, after conservatism has failed.

As we belong to the conservative group, as does Dr. Thorndike, I am afraid that my discussion may not be sufficiently critical. However, it is my impression that the acromioclavicular separations that we see are possibly a little more severe, in general, than the ones that Dr. Thorndike sees, the degree of forces being greater which have produced the injury in our cases.

In the last twenty-one cases that we have had of these injuries, three were very severe with marked displacement. One of these patients out of the twenty-one cases came to us three weeks late with marked separation and a very painful shoulder. We treated this individual conservatively for five weeks, and the pain in the shoulder persisted. We resorted to operation, and we did much the type of operation described by Dr. Speed.

I would like to show a dressing that we have used for the more severe types of injuries. (Fig. 10A.) Dr. Miller, our surgical resident, devised this. It was simply a modification of the Jones' brachioclavicular splint or

dressing, and very much like Howards'. We placed a posterior right angle plaster splint or a very light circular cast on the arm to hold the arm at right angles. Then with the sponge rubber pad over the clavicle, we make



A B

FIG. 10. A, type of brachioclavicular dressing for acromioclavicular separations; anterior view. B, posterior view of brachioclavicular dressing.

pressure down on the clavicle, lifting the arm upward by the use of adhesive strapping or elastic bandage. Figure 10B is the posterior view.

I believe that for the severe injuries, a little more controlled immobilization is necessary than described by Dr. Thorndike.

The point about aseptic necrosis, I think, was a very interesting one. We have not observed this lesion in our injuries.

Again I would like to say that I have enjoyed Dr. Thorndike's paper.

ARTHUR R. METZ (Chicago, Ill.): Dr. Thorndike has given us a very nice description of the anatomy about the acromioclavicular joint, which makes the treatment appear very simple. In our experience dealing largely with railway men in whom the shoulder injuries sometimes are rather severe, it is impossible to hold the dislocation of the clavicle by strapping with adhesive.

Injuries of this type are *x*-rayed with the patient standing so that the dislocation shows its maximum displacement, which is usually one-half to three-quarters of an inch. Such displacements we have not been able to hold down by strapping or by a pressure bandage which runs over shoulder and around below the elbow.

In working men over twenty-five years of age we regard this a major injury which may be very disabling.

In manipulation of such an injury under the fluoroscope, it will be observed that the acromium approximates the outer end of the clavicle when the elbow is elevated to about the level of the ear. As a result of this observation we treat all recent injuries to the acromioclavicular joint, with actual separation, by putting the patient to bed for three weeks with his arm suspended so that the elbow is on a level with the ear. This treatment, as a rule, gives good results in six to twelve weeks.

Patients who have not been treated are occasionally seen in which the dislocation has persisted and the patients are able to continue at heavy manual labor.

Dr. Frasier Gurd, of Montreal, presented a case before the Fracture Committee in which the entire clavicle had been resected and the patient returned to regular manual work.

It would seem that with the excellent results reported by Dr. Thorndike and Dr. Quigley that we have the choice of three different methods of treatment of injuries to the acromioclavicular joint, depending upon the severity of injury and age of the patient: (1) Strapping the shoulder with adhesive in young athletic individuals, in which damage is not too great; (2) in more severe cases and older patients, rest in bed for three weeks with elbow elevated to level of the ear; and (3) resection of the outer portion of the clavicle or entire clavicle if the condition becomes disabling.

Gordon Murray (Toronto, Ontario): I believe I am one of the culprits to whom Dr. Thorndike referred when he said we preferred to use pins and spikes and screws, and other obnoxious things, in this joint.

First of all, I enjoyed his paper very much indeed. I think in the ordinary dislocation, function is returned fairly well. However, when the coracoclavicular ligaments are torn, it is a different matter; and it is a different matter also in women in whom deformity is of great importance.

In those people we have had best results by putting a wire through the joint, putting it through the deltoid, through the acromion and into the clavicle. In our cases with coracoclavicular dislocation and wide separation we have had excellent results. We were able to hold them quite satisfactorily with one or two pins, and in the ordinary dislocation of the acromioclavicular joint alone, the results have been excellent.

These people are able to continue at work, provided it is not laboring work, beginning on the second or third day. One patient with a coracoclavicular dislocation had it fixed up, came back in two weeks and said he was feeling well. We discovered shortly that he had returned to work as a laborer. I asked him what sort of weights he was lifting, and he said, well, he did not lift anything more than two hundred pounds. He has a perfectly satisfactory result.

I believe, at least in my hands, that to be certain of a good cosmetic as well as functional result, there is no disadvantage and there are some advantages in passing a pin through this joint. Usually the pin must be taken out at a later date.

Martin C. Lindem (Salt Lake City, Utah): I would like to call attention to a complication encountered which has not been mentioned by Dr. Thorndike, and that is osteochondritis of the joint. The appearance, probably, in the *x*-ray was very similar to the case he showed with a cystic degeneration at the end of the clavicle, but in this joint where was a collection of half a dozen pieces of bone, which were covered all around with cartilage, very similar to or identical in gross appearance to an osteo-

chondritis of the knee-joint after separation of a foreign body. The joint also contained thin, serous fluid.

The joint was cleared of the foreign body, the cartilage surface was débrided as one would do in a knee joint. The covering of the joint was closed without any fixation of the bones, and there has been a completely good function.

FRASER B. GURD (Montreal, Canada): Dr. Metz has referred to the fact that last year in February before the Fracture Committee, I showed a couple of cases, and will show the same pictures now that I used at that time, apologizing to those Fellows who were present last year at that meeting.

The pictures of these three cases, in two of whom the lateral third of the clavicle was resected on account of acromioclavicular dislocation and, in the third, complete resection of the clavicle was performed seventeen years ago for sarcoma, proves that there is no deformity and no loss of function in consequence of this form of interference. This subject was presented before the Ann Arbor Meeting of the Central Surgical Association recently. The pictures will be published in its discussion.

My thesis in the matter is that the clavicle is one of the spare parts, as far as the human anatomy is concerned, and that any part of it or the whole of it may be removed without disability, and that in consequence, for the severe type of either marginal fracture or complete dislocation of the acromioclavicular joint, particularly if it is of long standing, a simple conservative method of treatment is the resection of the lateral third, or thereabout, of the clavicle.

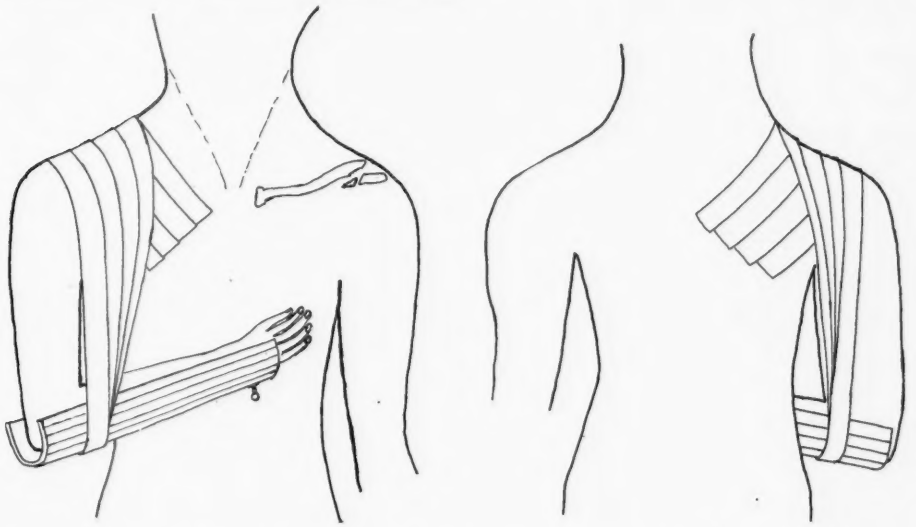
DONALD GORDON (New York, N. Y.): Some years ago, when the infections of the operating room did not afford the same freedom in operating on bone cases as is the case today and these problems presented themselves to us in the out-patient department I had occasion to try the old Stimson method. I immediately found disadvantages in it, due to the fact of the pain caused by the pressure of the adhesive where it passed over and supported the upper part of the ulnar.

To meet that, I put a co-aptation splint, using a padded co-aptation splint for the forearm and hand to rest in. Figure 11A is the front view showing the adhesive fanned out so that it might have an adequate pull on the trapezius. You will note a little ring in the distal end of the splint near the hand. With the patient ambulatory, the weight of the forearm pressing down, as it will by the action of gravity, will pull on the muscles which tend to elevate the outer portion of the clavicle.

I also found that this was more successful in the type of dislocation in which there was an associated fracture of the outer end of the clavicle, as shown on the right hand side of the slide.

Figure 11B is the posterior view. To make this active at night when the patient was in bed, I utilized the same weight traction gadget as suggested in the hanging cast, attaching the cord to the ring in the distal end of the splint.

I appreciate very much the simplicity of Dr. Thorndike's method, and I think that it, in combination with the suggestion of Dr. Winfield, shown in his picture, appears to me that it might be called the "hanging adhesive," or the "hanging adhesive plaster cast."



A B

FIG. 11. Modification of Stimson dressing for acromioclavicular dislocation. A is the front view; B the back view.

AUGUSTUS THORNDIKE, JR. (closing): I want to thank the gentlemen who expressed their own principles quite frankly. I still, however, believe that we are fortunate in seeing these cases immediately, instead of an hour, six hours or longer afterward. If one can apply that fixation immediately, I am certain that one can hold that clavicle down on the acromion.

I do not know much about the railroad man and climbing, but I am sure that this boy here could have climbed up a box car perfectly well in the three weeks without having laid in bed. He has been ambulatory at all times and even prior to my seeing him, the dislocation having occurred fourteen days previously.

Concerning the deformity in women, I have had no experience with trying to satisfy the cosmetic results. I can see where that could be quite different. I believe that even if the wire or pin has to be removed, it is probably worthwhile for a short period.

In reference to osteochondritis, probably I used the wrong term in describing that rarefaction that appears at the end of the clavicle by calling it aseptic necrosis, but this patient was not operated upon, and the *x*-ray appearance changed to normal over the course of three months, so that the cystic appearance and the irregularities were all smoothed out.

I want to thank you gentlemen very much for being so forebearing about a very simple little type of treatment for such injuries as the acromioclavicular joint receives.

# COMPLICATING FACTORS IN THE TREATMENT OF INJURIES TO THE MENISCI OF THE KNEE JOINT*

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THIS paper is not intended to deal with the diagnosis or treatment of meniscus injuries *per se*. In it will be discussed the various factors, exclusive of the meniscus injury itself, which we have found to influence the success of surgical treatment in respect to ultimate result and to disability time. It does not represent a purely statistical study, but rather attempts to analyze the experience of a hospital staff in dealing with these lesions over a period of thirteen years.

In evaluating this experience one must consider that 461 knee joints have been operated upon in this period, 79 per cent of which have had a history of trauma directly leading to the symptomatology and need for treatment, and of these 315 have had meniscus injuries proved at operation. These latter represent the patients operated upon out of a group of 631 cases in which the clinical diagnosis of meniscus lesion had been made, the remainder having been treated conservatively according to a rationale which will be outlined later in the discussion. Of the 631 cases 86 per cent were diagnosed as clinically certain lesions of the medial meniscus and 14 per cent were considered similarly as involving the lateral meniscus. Of the patients operated upon 85 per cent proved to be medial meniscus injuries and 15 per cent involved the lateral meniscus. In 10 per cent both menisci were involved. In addition to these 631 cases of clinically definite or operatively proved meniscus injuries, there were seen 623 cases of knee joint trauma diagnosed as sprain in the absence of definite clinical evidence of a specific lesion. One hundred one of these showed a hemorthrosis sufficient in amount to warrant therapeutic aspiration. All of these 623 cases were handled conserva-

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tively, i.e., without operation, and are cited here merely to point out the fact that doubtful or vague diagnostic pictures were not considered in the group of cases forming the basis for the conclusions here voiced.

Another point of importance in the evaluation of this experience is the fact that the conclusions expressed are not a reflection of the writer's personal opinions, but represent the consensus on the service as a whole. Each case, while the patient was under treatment, has been openly and freely discussed by all members of the staff at our weekly staff conferences, and on every follow-up visit the findings as to anatomy, function, symptoms and economic rehabilitation have again been the subject of open and free discussion by the whole staff. Over 80 per cent of the cases have been thus followed for from two to five years after operation.

On the basis, then, of this experience, I will attempt to set down the factors which we believe are of importance in complicating the care of these patients.

The first factor for discussion is that of the rapid and profound hypotonia and atrophy of the rectus femoris, the vastus intermedius, and the vastus internus which ensues following intra-articular damage to the knee joint. It is not an atrophy of disuse; it is well marked by the fifth day after injury in many cases, and always by the tenth day. While the atrophy has in some cases resulted in a two and one-half inch lessening in the circumference of the thigh 20 cm. above the tibial articular margin, the hypotonia is the most striking feature of the picture presented. With this atrophy and hypotonia there is frequently loss of ability to contract the rectus voluntarily, and to less degree the internal vastus. The nature of this curious phenomenon has never been accurately determined. Experimentally, it has been definitely shown that an identical phenomenon can be produced in the thigh extensors of the dog by removing a meniscus from the knee joint, and that its occurrence can be prevented if the knee joint is denervated before the operation is done. This experimental evidence is quite definite and quite striking. The vastus lateralis, in both clinical cases and in the experimental animal, seems relatively less affected by atrophy and hypotonia, and the power of voluntary contraction in this muscle is better maintained. When an operative procedure is performed on the joint it acts as an additional intra-articular trauma, and the atrophy, hypotonia, and loss of power of voluntary contraction are intensified. When a knee joint is subjected to repeated traumas over a period of months or years, as

by a recurring dislocating bucket handle cartilage, this atrophy and hypotonia become more or less "fixed," and even under excellent care many months may elapse postoperatively in such a case before extensor muscle power is regained. Brantigan and Voshell[1] have published recently an excellent and clear-cut presentation of the integrated functions of the knee joint ligaments as demonstrated in cadaver experimental specimens. In the living subject, however, we believe that the function of these ligaments is a reserve function, utilized only when the stabilizing action of the normal musculature is caught "unawares" by a sudden and unexpected twist or lateral bend at the knee, or when the stabilizing power of the musculature is exceeded by the force of the trauma involved. We further believe that if the stabilizing power of the musculature on the knee joint is deficient, and the ligaments are therefore called upon to act as stabilizers per primam and to act continuously as such (instead of playing the part of reserve checkreins as occasion demands) low-grade inflammatory reaction—the so-called traumatic arthritis—will result with secondary changes in the synovia, in the fat pads, and in the articular cartilage covering the lower femur, the patella and the upper tibia. This question of clinical knee joint stability has been discussed by Darrach,[2] who rightfully stressed the point that complete ligamentous stability of the knee joint is clinically demonstrable only in complete extension and in complete flexion, the two positions which are very rarely assumed by the human knee joint in ordinary activities.

We, therefore, believe that next to the elimination of the pathological condition of the knee joint the most important factor in satisfactory results in meniscus injuries, both in regard to the ultimate outcome and to the rapidity with which full and unlimited function can be secured, is restoration of the lost muscle tone in the knee extensor apparatus and the elimination of the atrophy which affects the extensor muscles.

This belief affects our procedure in meniscus lesions in several ways. We do not believe in repeated attempts at conservative treatment in recurrent meniscus lesions. A certain percentage of primary meniscus lesions undoubtedly entail tearing of the attachment of the meniscus to the lateral ligament of the joint and the adjacent capsule, which, as Brantigan and Voshell[1] have shown, is of rather loose texture, or of tearing loose of the anterior or posterior attachments of the menisci. The rest are tears through the meniscus itself, bucket handles or flap tears. We know of no way in which these two types of

lesion can be distinguished one from the other clinically. We believe that the ligamentous tears will heal if the meniscus can be held in relation with its normal contacts by extension of the knee, and that the tears through the meniscus itself will not heal. The experimental work of King[3] on this point is quite convincing. Since we are unable to differentiate between the two lesions clinically, and since we know of no data as to the relative frequency of the two, we treat all first meniscus lesions conservatively, *if possible*. Only those which evidence locking of the joint, and in which the locking cannot be reduced under an anesthetic, are urged to undergo primary operation. The others, those which have not locked, and those in which reduction of the locking has been possible, are aspirated if the hemarthrosis is large, and are then placed in extension in a circular plaster from groin to ankle. This is applied over stockinette only, with thin felt strip padding about essential bony points. The patient from then on is urged to walk about as much as possible on the extremity, using crutch or cane support for only as few days as possible, and to practise quadriceps contraction exercises at as nearly hourly intervals as possible for the next four weeks or so. If at all possible, he is returned to his ordinary occupation during this time. At the end of this period the circular plaster is removed and the natural exercise of the extremity plus the quadriceps contraction exercises are continued until the hypotonia and atrophy are eliminated. Any physical therapy which is used, and we prefer if possible to use none, is used for the relief of soreness and stiff feeling only, and in order that the patient may more easily and comfortably give the part exercise and use; and he is advised in no uncertain terms on that score. Three hundred sixteen clinically certain meniscus injuries so treated recovered completely without operation and without recurrence during the follow-up period. We are certain that in many of these cases, had immobilization been practised without the stress on use and exercise as the essential feature of treatment, relative instability of the knee would have resulted with secondary joint lesions leading to prolonged disability, and in some cases, the need for late operative procedures for the relief of these secondary lesions.

If, following conservative treatment such as described above, a recurrence of symptoms occurs, or if primarily the locked knee cannot be made to extend, operative treatment is initiated. In the two-day period which we reserve for preoperative preparation in these cases the patient is instructed in quadriceps exercises if he is a primary operative case or if he is a recurrent case not previously

treated by us. This is of course not necessary in the recurrent cases whose initial care was in our hands. Postoperative patients have a moderate pressure dressing applied for twenty-four to forty-eight hours, but start their quadriceps contraction exercises at the end of twenty-four hours. When postoperative quadriceps contraction is difficult to initiate it is aided by the use of the Smart coil to give nonspastic rhythmical contraction. It is frequently of value to teach the patient to contract first his good quadriceps, then attempt the contraction of the involved one, and then both sides simultaneously to a rhythmic count of 1-2-3. The value of such rhythmic bilateral exercise in breaking through the bar to voluntary contraction of the muscle is considerable, and it can be taught easily to the patient in the preoperative period. Voluntary knee bending is started when the pressure bandage is removed. The patient is up in a chair on the fourth day on the average, sometimes as early as the second or third day, is walking with crutches on the fifth or sixth day, and leaves the hospital walking without support or in some cases with a cane on the average on the ninth day. Frequent short periods of walking exercise are urged during the hospital stay and the quadriceps exercises are kept up in the hospital and later in the out-patient department. There is no question in our minds but that the rapidity of functional and economic rehabilitation in these cases is in direct proportion to the degree to which the patient can be made to carry out the restoration of his quadriceps muscle tone through voluntary exercise and use. Keeping a patient on crutches, deluging him with physical therapy, and postoperative immobilization of the knee joint are all conducive to delay in functional and economic rehabilitation.

In the cases of repeated recurrent meniscus lesions with marked atrophy and hypotonia, even more intensive attention to this factor is essential to success. In order that walking and exercise may be carried out without crutch support and yet without symptoms of pain and swelling in the extreme cases, it is wise sometimes to provide the patient with a jointed knee cage which will not interfere with motion but which will provide lateral stability until his muscles can do so. But he must be made to understand that its only purpose is to make it possible for him to practise an increased amount of normal exercise and use of the leg.

The second complicating factor which enters this discussion is the question of the incision used in the operative removal of menisci. It is, of course, not only possible, but usually quite easy, to remove a meniscus through any one of the small incisions frequently used on

either side of the joint; and if there is any difficulty in getting at the posterior attachment, an accessory incision in front of the biceps or the semi-membranosus will take care of it. But we have come to believe in the last thirteen years that the procedure is unwise. This belief is based on our proved inability to make the diagnosis of a meniscus lesion as the sole pathological condition present. In cases so diagnosed only 30 per cent of the knee joints have shown the meniscus to be the sole lesion. Seventy per cent of the cases have shown at least two lesions and over half of this 70 per cent have shown anywhere from three to eleven lesions in the joint. Darrach[2] reported on a six-year section of these cases in 1935 with very similar figures. Hypertrophied and fringed alar fat pads showing definite evidence of injury; softening, fraying, erosion and partial detachment of the articular cartilage on the femoral condyles, the posterior aspect of the patella, and the tibial articular surface; loose fragments of articular cartilage, often small, within the joint; hypertrophic spurs; unsuspected crucial ligament injuries presenting projecting stumps within the joint; unsuspected bilateral meniscus injuries; unsuspected synovial changes—these are some of the unexpected pathological lesions found. The high percentage of bilateral cartilage injuries—10 per cent—is possibly explainable on the basis of their being discovered by reason of more adequate exposure of the joint. In our earlier years, when we used the small incision, many of these were missed, and, as a result of continued pathological conditions in the joint, muscle hypotonia and atrophy persisted even after removal of the meniscus. We now use a long internal or external parapatellar incision, running from the top of the quadriceps pouch to below the tibial margin, which gives complete exposure of the joint when the patella is retracted to one side and the joint flexed. Wounds heal from side-to-side—not from end-to-end—and the length of the incision has not caused any increase in our convalescence time. On the contrary, with the removal of all pathological conditions present in the joint and concentration on the restoration of muscle activity postoperatively, unhampered by the deterrent effect of residual joint pathology, our convalescence time and functional and economic rehabilitation time have decreased, even as compared with the published findings of Darrach[2] in 1935. We, therefore, believe that adequate exploration of the joint is indicated in operations for the removal of a meniscus, and the concensus on our service is that we cannot get exposure for adequate exploration through the small incisions frequently used. The methods of dealing with the individual conditions have been

outlined by Darrach[2,4] in previous publications. Many of the degenerative changes in the articular cartilaginous surfaces and many of the synovial changes may be due, we believe, to the instability of the joint in cases of any standing, secondary to the loss of tone in the quadriceps extensor mechanism as much as, if not more than, to the direct effect of the presence of a loose and torn cartilage. We have not as yet found it necessary to do an anterior crucial ligament repair in order to restore stability to a knee joint, although in 8 per cent of our cases the anterior crucial was found completely torn, and in 6 per cent partially torn. Projecting stumps of anterior crucial ligament attachments have been removed. Our percentage of posterior crucial ligament injuries has been small—only a little over 1 per cent—but in only one case has the knee joint been unstable for a considerable time after operation although none of them were repaired. This case was one of long standing injury, with "fixed" atrophy and hypotonia whose co-operation in restoring muscle tone and regaining muscle power was minimal. It took two years to regain functional stability in his joint. It is possible that in this case time might have been saved in restoration of stability if a posterior crucial replacement operation had been done; but in general we believe that crucial ligament instabilities are best handled by intensively striving for the regaining of muscle tone and volume, and that operative repair should be reserved for those cases in which this proves impossible.

The third factor warranting discussion is the use of the tourniquet. There can be no question but that with its use operating time is cut down materially, and this is a definite advantage provided that time is not saved at the expense of the patient's subsequent welfare. With our conviction that adequate exploration of the whole joint is indicated in all operations based on a diagnosis of a meniscus lesion, the use of a tourniquet enforces anoxemia of the extremity below it for anywhere from forty-five to seventy-five minutes or more, using the Lane technic. In an extremity already compromised by loss of muscle tone and strength, we have been unable to believe that this enforced anoxemia was a matter of no import. We think, on the basis of our results, that we are justified in the use of the Lane technic and in the exploration of the whole joint. On the other hand, operating on a knee joint through a large incision under ordinary conditions without a tourniquet is apt to be a very bloody and messy procedure with visibility definitely clouded. We have finally worked out a technic which allows of the operation with very little bleeding indeed,

and that relatively easily controlled, and does away with the use of the tourniquet. The table, while the patient is prepared and draped, is placed in high Trendelenburg position, with the knee joint line just distal to the line of break in the foot piece of the table. This effectually drains the venous circulation. When the skin incision is made, the bleeders are surprisingly few in comparison with the patient in a flat position, and are dealt with by mosquito clamp and cautery as encountered. The towels are then clipped to the wound and the incision through the capsule and in the interval between the rectus tendon and the vastus medialis or vastus lateralis similarly dealt with before the synovia is opened. With a then dry field the synovia is opened, the patella retracted and the foot piece of the table dropped, leaving the thigh in the Trendelenburg position with the knee flexed at right angles over the edge of the table. With the complete exposure of the joint gross bleeding points can be dealt with by mosquito clamp and cautery. Bleeding ceases to be a factor of any importance with the use of this method, and a remarkably dry joint can be ensured. When the surgery on the interior of the joint is accomplished, the knee is again extended and the patient is lowered from the Trendelenburg position to the flat position, and any additional bleeding points then apparent are dealt with.

In suturing the incision, after thorough lavage of the joint with saline, the synovia is left unsutured so that any ooze which may occur can possibly escape from the joint into the surrounding tissues. A moderate cotton pressure bandage or Ace elastic bandage over dressings is then applied. We believe that since we have adopted this method we have fewer postoperative joint fluid collections, that we have less difficulty in getting our muscle rehabilitation started, and that we have fewer knee joint reactions postoperatively. By this latter term I refer to the occasional patient who runs a temperature with a relatively normal white and polymorphonuclear count but a high sedimentation rate, and acute pain and knee joint effusion for some days postoperatively. Before we embarked on the present technic this reaction occurred in 4.6 per cent of our cases. Cultures of both the wound and of fluid aspirated from the joint were negative in all these cases, and wound healing was normal. We believe that the prolonged use of the tourniquet and postoperative bleeding into the joint and capsular structures may have been responsible. Certainly there has been a marked decline in these cases since the adoption of the present routine, and we have not seen one for some time.

In this series of 315 cases there have been three infections. Two of these were in knee joints subjected to diagnostic air injection preceding operation seven or eight years ago. The third case was a streptococcic infection occurring during an epidemic of five clean wound infections on the service recently. There was no demonstrable source for this infection. All three patients recovered, but with marked limitation of function in two and bony ankylosis in the third.

In conclusion I might state a personal conviction that in general the supposed results of excision of the menisci of the knee joint, insofar as complete restoration of muscle tone and muscle power with complete functional stability of the knee, both in respect to the ultimate result and the time required to obtain it, are somewhat like the results supposed to be generally obtained in Colles' fractures. They are popularly dismissed with the bland assertion that the results are good. Adequate follow-up studies on Colles' fractures have shown that this assumption is not true in a reasonably large percentage of cases. From the experiences of our own clinic, and from what I have seen elsewhere throughout the country I believe the same holds true for meniscus lesions. I have attempted, in citing our experiences, to call attention to some of the factors which we believe to have been involved in influencing the ultimate result and the rehabilitation time in these cases as handled by us.

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## DISCUSSION

Melvin S. Henderson (Rochester, Minn.): Dr. Murray's paper is interesting and stimulating. He mentions many controversial points we might take up, such as the use of the tourniquet and the length of time required for the operation he describes, but discussions of that character cannot well be carried on here.

My contribution to the discussion of this paper is an attempt to show that it is high time we took an interest in our end results in knee joint surgery involving the menisci. The statistics in my first lantern slide, made in 1934, show that in a total of 343 operations wherein the menisci were

removed, fracture or distinct damage of the meniscus was evident in 221 cases; but in 122, no fracture was demonstrable, although occasionally we did make the note that the cartilage was thin, frayed or loose. Recently I have reviewed our statistics and we can now add to the 343 cases, 173 more making a total of 516 cases in which the cartilage was removed. However, even in the light of the increased experience, I find that positive pathological conditions found are no higher in the larger group than they were in the previous group reported in 1934.

Basing the statistics on the 1934 group, we found complete relief in 77 per cent, improvement in 14.4 per cent; and no relief in the balance. In reviewing the records of sixty-nine patients, concerning whom a note had been made at the time of surgery that we could find nothing wrong with the cartilage and that the pathological condition found was insufficient to account for the symptoms, only 27 per cent obtained relief. Perhaps if we had closed those knees without removing the cartilage, the result would have been nearly as good.

It is interesting to note that Dr. Murray believes damage to the anterior crucial ligament is of very minor importance. It is my belief that many of the unsatisfactory results following removal of the meniscus are due to the fact that the anterior crucial ligament was torn or stretched at the time of the injury and that the symptoms which persisted were those resulting from injury of that ligament. Such papers as Dr. Murray's are needed; it is evident that his experience must have been similar to ours, namely, that there are too many indifferent results in this type of surgery and that he is deliberately making his operation more painstaking to see if the results cannot be improved. I shall enjoy reading the complete paper when it is published.

Paul B. Magnuson (Chicago, Ill.): I am tremendously disappointed in Dr. Murray, because I find myself for the first time almost in history, agreeing with him on almost everything he says. Consequently, I find it difficult to discuss his paper satisfactorily myself.

I have done considerable experimental work on knees, and have found myself in diagnosis very deficient, as apparently Dr. Henderson admits to being, which is consoling. There is nothing, I think, in the line of bone and joint diagnosis that is much more difficult than telling why a knee slips, clicks or locks or gives way of which the patient often complains.

Now, there is no doubt but what the mechanics of the knee are responsible in a fairly large number of cases; there is a bearing surface which must work on two curves, which must synchronize in all motions of the knee, and once there is a little divergence in the rotating arc of the tibia around the condyles of the femur, there is irritation.

Irritation in a joint, if often repeated, sets up some form of arthritis in the joint. A true picture of hypertrophic arthritis can be produced in dogs by cutting the internal lateral and crucial ligaments and allowing the dog free

exercise. It will not be produced if that dog is put in the ordinary laboratory cage. He has to be taken out where he can have free exercise.

Then, almost universally, those animals will develop a true picture of hypertrophic arthritis with spurs, and after they appear the erosion of the cartilage starts. That can be traced in definite proportion to the amount of exercise the dog has had and the length of time he has had that exercise.

Often repeated, small trauma has a definite effect on the production of erosion of the cartilage.

There are two kinds of degeneration of cartilage: One starts at the matrix, the other at the surface. The degeneration that starts at the matrix is wider at the base, and comes to a cone-shaped end at the surface. It shows degeneration starting below.

I do not believe we see that type of degeneration in purely traumatic arthritis. In my experience, the traumatic cases have degeneration of the cartilage at the surface, progressing toward the matrix.

Dr. Murray called your attention to the fact that he shaves the dead cartilage off down to the place where he finds normal or glistening hyaline cartilage. In many of these cases, especially on the weight-bearing surfaces which have had irritation of the joint, we find roughening of the surface, a granular surface, a villous-looking surface of cartilage, not villi growing in from the synovia, but an appearance of the cartilage that almost looks like coarse velvet. When this is cut or shaved off parallel with the matrix, we find that depending on the length of the time that the degeneration has lasted and the severity of it, we get down to normal hyaline cartilage. That will develop from the matrix if it has an area on the matrix's left. If it has no healthy matrix underneath, it will continue that degeneration.

These cartilage cells on the surface will show condensation of nuclei, threading out of the cartilage and poor staining qualities, while down below, the nearer you get to the matrix the more normal and growing cartilaginous cells appear. Therefore, I think we can fairly assume that the more rough spots that we have in the joint, whether they are due to irritations caused by semi-lunar displacements or fractures, or to a wobbly joint, or to trauma at some distant period which has knocked up small pieces of cartilage, the greater the necessity for adequately dealing with this pathological tissue. A piece of cartilage which is knocked up away from the matrix will degenerate into fibrocartilage in three weeks in experimental animals, and then float around in the joint and act as a mechanical irritant. We find these things in weight-bearing joints as well as in the elbows of boxers and bowlers. The strange thing is that boxers have it more frequently on the end of the humerus, on the condyles, and the bowlers have it on the articular surface of the olecranon.

KELLOG SPEED (Chicago, Ill.): Just as we make mistakes in abdominal diagnoses, and abdomens are opened for certain things which are found not to be present, I find that a similar situation exists in the knee joint.

I would like to show three slides illustrating some of my experiences in the diagnosis of so-called cartilage fractures or injuries in which other things were found. The results may be dependent upon these unknown or unexplored or unbelieved complicating pathological conditions, consequently the clinical pathological condition may be worth while inquiring into.

In a series of three hundred cases, the joint was always found sterile. There was osteochondritis in eighty of them. Pre-existing pathological conditions may exist at the time of the diagnosis of cartilage injury, and these complications include the various things listed: habitual dislocation of the patella, loose bodies in the joint, old arthritis, tuberculosis of the knee, abscess, traumatic penetration of the knee, a double patella, ruptured tendons, and so on down the list, including osteo-arthritis, peri-articular gangliomas, traumatic neuritis, etc.

All those things must be considered, and they may have a bearing on the outcome and the result after an operation for cartilage removal.

THOMAS H. PETERSON (Boston, Mass.): I just want to put in a word for you who have not tried the posterior incision as described by Dr. Cave. I recently had an opportunity to compare, bed for bed, three different types of incisions on a number of cases, and I will say that from the standpoint of earlier and more rapid regaining of normal motion of the knee, I have found without any question in my mind, that the patients who had the posterior type of incision for the removal of the semilunar cartilage had a much more rapid return to normal motion than those who had other types of incision.

Dr. Cave, as you know, claims that it is much easier to remove the posterior portion of the cartilage that way, and I certainly agree with him, although I do not think that it is entirely necessary in every case. On the other hand, if you are going to explore the knee as you do in the straight or parapatella incisions, the posterior incision is not satisfactory.

But I do believe that the posterior type of incision gives a much more rapid return of normal motion than that of any of the other types which I have had the opportunity to try.

# REGENERATION IN THE ULNAR, MEDIAN AND RADIAL NERVES*

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THE problem of regeneration of injured nerves is dealt with extensively in the literature, but for the most part concerns itself with physiological experiments on laboratory animals. From a practical point of view, we are concerned less with the actual physiology of regeneration than with the ways and means of ensuring that normal physiological regeneration take place in a given instance and what may be expected as to prognosis under varying situations.

The problem of ensuring regeneration of nerves has been dealt with by numerous authors and is well understood, although modifications of treatment are still being originated. The question of prognosis has evoked many instances of personal opinion, but for the most part there has been a failure to substantiate these with clinical facts. In this report we shall summarize the experiences of the Massachusetts General Hospital for the past ten years with injured nerves to the upper extremities, and endeavor to formulate prognostic guides that may prove of assistance to others.

The study of regeneration of nerves has several inherent difficulties: The duration of time involved makes it almost impossible for one man to follow any considerable number of patients to an end result and certainly even in an institution such as the Massachusetts General Hospital, the varying expressions of opinion as to progress found on records become very perplexing. Then, too, the determination of the exact time at which regeneration may be said to have begun and at which it has reached an end stage requires arbitrary decisions and may involve considerable error. More difficult still is the definition of what exactly constitutes good and poor results.

In the past ten years at the Massachusetts General Hospital we have found records of 147 instances of injured nerves of the arm. Of these we have reasonably good evidence as to the eventual result in 110 or 75 per cent. The results were obtained in eighty-one patients

* From the Hand Clinic of the Massachusetts General Hospital, Boston.

by personal observation in the hand or fracture follow-up clinics, in eleven instances by letter, which at least gives subjective impressions, and in eighteen instances from information supplied by various observers on their records.

Classification of results, as has been mentioned, is probably the greatest stumbling block for the reader of reports on follow-up of nerve injuries. As Pollock and Davis[1] point out in the collection of reports they have assembled from twenty-one authors, if criteria of success are mentioned, which frequently they are not, no two authors have fixed upon precisely the same yard stick by which to distinguish a good result from a poor one. It has seemed to us that the prime requisite by which to determine the success or failure of treatment to an injured nerve is the ultimate usefulness of the hand and arm to the patient. As it is obvious that what might serve a day laborer with complete satisfaction might prove entirely useless to a skilled craftsman or a musician, we have chosen to employ as a standard a hand that would prove useful for ordinary occupation and average everyday life. We have arbitrarily ruled that a hand with areas of anesthesia or hypesthesia to a marked degree cannot be considered useful not only because of the lack of sense of touch, but also because of the danger from burns and other injuries.

With the possible exception of the opponens pollicis, the intrinsic muscles of the hand supplied by the ulnar and median nerves are individually not of great importance; therefore, it is return of sensation that is essential as regards injuries to those two nerves, at least in the forearm. Regeneration of the sensory function of the radial nerve, on the contrary, is unnecessary for a hand to be considered useful, but the motor component must be present in order that a hand be so classified.

It may be said at the outset that in no instance in which physiological transection of the nerve occurred, have we observed 100 per cent regeneration, either in the sensory or motor components; although in a few patients improvement was still taking place years after a good result may have been said to have been attained, so that it is possible that we have not followed our cases over a long enough period of time. Accordingly, we have classified two cases as poor results that can be shown to have sensation throughout the nerve distribution area, but the hypesthesia is so marked as to interfere with the usefulness of the hand.

As may be seen from Table 1, we have classified 84.5 per cent of the nerves that we were able to follow for a sufficient period of time

as good results. This is a somewhat higher figure than is given in most reported series, which average about 65 per cent good results, but we have been fortunate in the follow-up of our patients and in being able to furnish them occupational and physiotherapy over long periods of time. In addition, most of the reported series are derived from injuries sustained in the last war in which conditions were unfavorable both to follow-up and to therapy.

TABLE I

RESULTS IN 147 INJURED NERVES OF THE ARM

| | Total No. of Cases | End Result Determined in | | Good | | Poor |
|---|---|---|---|---|---|---|
| | | No. | Per Cent | No. | Per Cent | No. |
| Sutured | 88 | 65 | 73.8 | 51 | 78.4 | 14 |
| Neurolysis | 45 | 31 | 68.8 | 28 | 90.3 | 4 |
| No operation | 14 | 14 | 100 | 14 | 100 | 0 |
| Total | 147 | 110 | 74.8 | 93 | 84.5 | 18 |

We are not complacent about our results, for in too many instances the technical procedure employed was unfortunate and ill chosen and our results should be improved.

TABLE II

RESULTS IN FIFTY-FIVE INJURED ULNAR NERVES

| | Total No. Cases | Results Determined in | | Good | | Poor |
|---|---|---|---|---|---|---|
| | | No. | Per Cent | No. | Per Cent | No. |
| Sutured | 32 | 21 | 65 | 19 | 90.4 | 2 |
| Neurolysis | 21 | 11 | 52.3 | 9 | 81.8 | 2 |
| No operation | 2 | 2 | 100 | 2 | 100 | |
| Total | 55 | 34 | 61.8 | 30 | 88.2 | 4 |

About one-third of the total number of injured nerves were ulnar. Unfortunately, we could determine the ultimate function in less than two-thirds of the cases although the results were considerably better than in either the median or radial nerves.

Most of the injuries occurred at the wrist so that innervation of the intrinsic muscles of the hand was lost. This, while it produces some deformity, notably abduction and hyperextension of the meta-

carpophalangeal joints of the fifth and to a lesser extent of the fourth finger and loss of the adductor of the thumb, results in surprisingly little incapacity. Regeneration of the motor component of the ulnar nerve almost invariably took place, although it apparently lagged behind the sensory nerve. In no case, however, have we observed the return of function of the adductor of the fifth finger.

The intrinsic muscles supplied by the ulnar nerve undergo extensive atrophy when the nerve is divided; and before function can be re-established not only must the nerve regenerate, but the muscle must develop enough tone and strength to perform its function. Therefore, it is not surprising that evidence of motor regeneration lags well behind sensory regeneration. As regards the adductor of the fifth finger, we believe that our lack of success is attributable to incorrect splinting in the past in that not enough attention was paid to keeping the fifth finger in adduction. Harmer[2] has achieved some brilliant results by the use of ingenious splints.

It is of interest that sepsis played no part in our poor results since in six instances all did well. It is doubtful whether age is of importance as a prognostic factor, for although the patients with good results averaged twenty-one years old and those with poor results thirty-one years, yet of the four over fifty years, all had good results.

The time interval between injury and operation is usually considered of paramount importance. Most surgical textbooks infer that immediate suture is more likely to be successful than a secondary suture. Of our patients, those sutured within six hours of injury showed eight good and one poor result, whereas of those sutured one month or more after injury eleven were successful and one was a failure. Four of the latter were over two years and one was four years following division.

It is obvious that in determining the rate of regeneration one must know the distance from the site of injury to the termination of the nerve as well as the time interval between regeneration and either operation or, in instances in which no operation took place, the injury. In dealing with patients, neither of these factors usually is known and must be estimated. In our cases the distances were estimated and are probably accurate within reasonable limits. The time interval was taken from the first visit to the clinic after regeneration was noted to be complete. As several weeks may have passed between visits, there may well be a large error here, but certainly the error favors a conservative estimate.

The average estimated rate in seventeen cases was 1.24 mm. a day. The extreme range lay between 3.6 and 0.58 mm. a day. The true rate is probably closer to 1.5 mm.

The nerves that were not divided and did not require suture were in large part associated with fractures around the elbow. Two of these were not operated upon, three were merely freed from surrounding scar tissue, and eight were transplanted at the elbow. Both of the failures occurred in attempts at transplanting.

Because of the fact that many of this latter group did not have complete physiological division, it is impossible to determine the rate of regeneration. However, in these cases an average interval of eleven weeks occurred before beginning regeneration was noted and it was some thirty-six weeks before regeneration was complete in the average case. The extremes lay between one and twenty-eight weeks before regeneration began and between six and eighty-seven weeks before it became complete. The times, it may be said, fairly closely paralleled the estimated distance necessary for the regenerating nerve fibers to traverse. It was in two of these cases that our only complete return of motor function occurred.

It is of interest to note that all four of the failures we have recorded were attributable to improper technic. In the first instance a neuroma, which should have been excised, was split lengthwise and the distal nerve embedded in it. In the second case the nerve was sutured under too much tension. The third case involved an accidental severance of the nerve on attempting a transplantation at the elbow; and in the last instance a nerve was transplanted that apparently had been so traumatized that a resection and suture should have been performed.

Injuries to the median nerve comprise our largest group, both in the total number and in those we were able to follow.

The site of injury was about equally divided between the palm of the hand, where usually digital nerves were cut, and the wrist. A few digital nerves were severed in fingers and a few median nerves injured in the forearm and upper arm. Unless the nerve was involved in the upper arm, serious motor impairment was limited to the opponens pollicis, for the abductor of the thumb and the first and second lumbricals are relatively unimportant muscles as regards function of the hand. It is of interest that we have seen four instances of division of the median nerve in the wrist without paralysis of the opponens pollicis, indicating, that in these instances, either the motor branch arises from a higher level than is usually supposed or

that the muscle is innervated by another nerve. In addition one patient with ulnar and radial palsy associated with a fracture developed paralysis of the opponens without other evidence of median involvement. The median nerve was explored and found intact. Function eventually returned as the ulnar and radial nerves regenerated. From our follow-up studies we have found that good function has returned to the opponens in three cases out of six. In two of the three failures, function was taken over by the adductor, satisfactory for all but the most delicate movements. The third patient who had also an ulnar paresis required a tenorraphy. In general, by the time that sensation was complete, motor function had also returned.

TABLE III

RESULTS IN FIFTY-SEVEN INJURED MEDIAN NERVES

| | Total No. of Cases | Results Determined in | | Good | | Poor |
|---|---|---|---|---|---|---|
| | | No. | Per Cent | No. | Per Cent | No. |
| Sutured | 45 | 36 | 80 | 29 | 80.5 | 7 |
| Neurolysis | 11 | 8 | 72.7 | 8 | 100 | 0 |
| No operation | 1 | 1 | .... | 1 | ..... | 0 |
| Total | 57 | 45 | 78.9 | 37 | 82.2 | 7 |

The age of the patient certainly played no part in median regeneration, for while our good results averaged thirty years old, our poor results were only twenty-three.

The time interval between injury and suture was apparently more important than in the ulnar nerves. There was but one failure in ten nerves sutured within the first few hours following injury, while there were five failures out of twenty-one sutured more than three weeks following division. Only one successful suture was accomplished more than one year following injury, although five were over six months old. Sepsis again played no part, for in four instances all attained good results.

An estimate of the rate of regeneration was made as in the ulnar nerves. This was determined in twenty-one cases to average 1.09 mm. a day. The extremes lay between 2 and .50 mm. a day.

Of the nerve injuries that did not require suture all but two were associated with fractures, mostly of the upper humerus. These two followed aneurysms of the brachial and axillary arteries, and both successfully regenerated.

We could determine in only two instances when regeneration first became manifest, these were in twelve and seventy-seven weeks and regeneration was complete in fifty-two and 156 weeks, respectively. In four other patients completion of regeneration occurred in eight, seventeen, eighty-one and 104 weeks. As in the ulnar nerves the longer intervals were associated with a greater distance to be traversed by the regenerating nerve fibers.

TABLE IV
RESULTS IN THIRTY-FIVE INJURED RADIAL NERVES

| | Total No. of Cases | Results Determined in | | Good | | Poor |
|---|---|---|---|---|---|---|
| | | No. | Per Cent | No. | Per Cent | No. |
| Sutured | 11 | 8 | 72.7 | 3 | 37.5 | 5 |
| Neurolysis | 13 | 13 | 100 | 11 | 84.6 | 2 |
| No operation | 11 | 11 | 100 | 11 | 100 | 0 |
| Total | 35 | 32 | 91.4 | 25 | 78.1 | 7 |

As may be seen in Table IV we have been able to trace the results of only thirty-two injured radial nerves and of these only eight had required suture. They are an interesting group, however, for the criteria of a good result depend almost entirely on motor regeneration. The area of sensation in the hand supplied by the radial nerve is variable, inconstant and may in large part be taken over by a "spread" from the median distribution.[3] It is of interest that once we observed sensory regeneration, though Bristow[4] says it never occurs.

Our poor results in sutured radial nerves are surprising, for an average of the twenty-one authors quoted by Pollock and Davis[1] indicates that the radial nerve should have the best prognosis and the ulnar the poorest, just the reverse of our series. However, the sparsity of our cases and the fact that all but two, both of which were successful, were sutured early in the ten-year period that we are examining may account in part for the discrepancy. It is perhaps also important that all the radial nerves were severed in the upper arm, and that the axones, certainly those of the sensory component, had a rather longer distance to traverse than in the cases of the ulnar and median nerve transections.

The cases are too few to attempt statistical analysis, but it may be mentioned that the three patients with good results averaged

sixteen years of age and were operated upon one and six-tenths months after injury, while the five with poor results averaged thirty-six years of age and repair of the nerves was not attempted until eight months after injury. Both sutured nerves in the two wounds that became infected regenerated. The rate of regeneration could be computed in only one patient, in whom it was 1.2 mm. a day.

In the thirteen patients whose radial nerves at exploration did not require suture, the results were much better. It is probable that in at least one of the two poor results the nerve was so damaged that resection and suture should have been done. In all except two, these cases were associated with open reduction at which time the nerve was found caught between fragments or embedded in callus. Of the remaining two, one was involved in an aneurysm of the brachial artery and the other with a cut of the upper arm; but although the nerve was found undamaged at operation, function never returned. In this group regeneration required an average of twenty-five weeks for completion, with extremes of four and fifty-two weeks. Two of the successful results followed operation more than a year after the injury.

TABLE V

RESULTS IN FIFTY-ONE NERVES INJURED IN ASSOCIATION WITH FRACTURES

| | | Total No. of Cases | Results Determined in | | Good | | Poor |
|---|---|---|---|---|---|---|---|
| | | | No. | Per Cent | No. | Per Cent | No. |
| Radial | Sutured | 1 | 1 | .... | 1 | .... | 0 |
| | Neurolysis | 12 | 11 | .... | 10 | .... | 1 |
| | No operation | 11 | 11 | .... | 11 | .... | 0 |
| Median | Sutured | 0 | 0 | .... | 0 | .... | 0 |
| | Neurolysis | 3 | 3 | .... | 3 | .... | 0 |
| | No operation | 2 | 2 | .... | 2 | .... | 0 |
| Ulnar | Sutured | 2 | 2 | .... | 2 | .... | 0 |
| | Neurolysis | 15 | 12 | .... | 11 | .... | 1 |
| | No operation | 5 | 5 | .... | 5 | .... | 0 |
| Total | ..... | 51 | 47 | 92.1 | 45 | 95.7 | 2 |

In eleven cases in which radial palsy was associated with fracture, no operative interference was adjudged necessary. Surprisingly, all the patients attained satisfactory results. In some instances it is impossible to say upon what basis this judgment was made. In

several, however, it is clear that only a partial palsy was found on clinical examination and it is probably safe to conclude that many of the cases could be so classified. Three of these were radial palsies that occurred following open reduction. Nevertheless, an average of six and five-tenths weeks was required before beginning regeneration was noted on the record and it was at an average of twenty-seven weeks before function was complete.

We have considered it of sufficient interest to record separately the results of nerve injuries associated solely with fractures. (Table v.)

They have all been considered separately under the headings of the various nerves, but we have grouped them together, primarily to show how seldom it has been found necessary to suture nerves so injured and also to indicate what good results may be expected.

Both poor results have been recorded before; the radial nerve was one which presumably should have been resected and sutured and the ulnar nerve was the one that was inadvertently divided while attempting a transplantation at the elbow.

Three of the nerve injuries followed rather than preceded open reduction, in each instance the operative note mentioned freeing the nerve and gently retracting it out of harm's way. It has been called to our attention that even with the greatest gentleness and utilization of every precaution accidents such as these may occur. In one instance the radial nerve was gently retracted with a single layer of rubber tissue from which was suspended a "Mosquito Snap." Even this delicate retraction proved excessive and a radial palsy that did not clear for six months resulted. One cannot advise the policy of not identifying nerves, for many would be inadvertently severed were this followed; but it is certainly true, that once the position of the nerve has been determined, the less interference with its course the fewer will be the subsequent nerve palsies. Nerves are freed from their normal relationships to a far greater extent than is usually necessary.

In our series, no nerve was permanently injured by operation, except the ulnar nerve mentioned above. By far the greater number of these nerve injuries were treated by neurolysis. In many instances this was attendant upon open reduction, but in others the decision to operate was made irrespective of the fracture. There has always been discussion as to the value of neurolysis as a therapeutic procedure, for if left alone, say the opponents, would not most of these nerves regenerate spontaneously?

No satisfactory single test has yet been devised to determine whether a given nerve will regenerate or not. The presence of a partial palsy or reduced sensation rather than paralysis and anesthesia is undoubtedly as good an indication that waiting may be pursued profitably as any other.

Frequently, the pathological condition found at operation justifies in most minds operative interference, and we may also point to those not infrequent instances of palsy coming on a long time after fracture of which we have two cases, in one of which weakness and hypesthesia did not become noticeable for twenty-one years, as further evidence that neurolysis may be advisable. These latter are associated particularly with fractures about the elbow causing impingement on the ulnar nerve. But after all, it is only by demonstrating that function has returned to nerves following neurolysis in which a sufficient period of time had elapsed for spontaneous regeneration to take place before operative interference was undertaken that we can answer the objections to the procedure with much conviction. Of our cases, twenty were subjected to neurolysis irrespective of the associated fracture. Of these, four operations were performed more than six months following the fracture, two were operated upon at the end of a year, and on three neurolysis was done three, four and eighteen years following fracture, all with successful outcome. It is impossible to prove the value of the operation in the remaining eleven cases, doubtless in some it was unnecessary, but we feel certain that as a therapeutic procedure it has a definite and important place.

Because of the difficulties in determining the extent of nerve injury and in recognizing the presence or absence of regeneration occurring spontaneously or after operation, a special study has been made in selected cases in hopes of developing more exact methods of examination than are usually employed. The familiar clinical tests for the presence of sensory loss, weakness, atrophy and vasomotor changes are all essential and need not be enlarged upon other than to emphasize their importance in following the course of all nerve injuries. There are many occasions when these tests are not conclusive until a period of months has passed and one looks for a more sensitive means of detecting early regeneration. This situation arises particularly in relation to the radial nerve where motor return may occur before sensory changes, in combined radial and median nerve injuries in which it is difficult to separate their sensory areas because of overlap, in facial paralysis in which sensory changes are not

present and in other cases in which sensory examinations are for some reason unsatisfactory.

Electrical tests have been tried with hopes of securing more

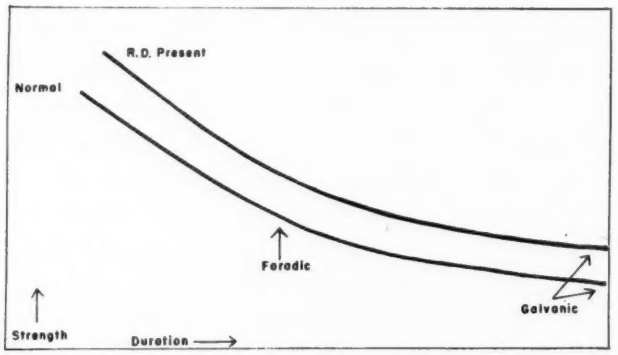


FIG. 1. Diagram showing normal strength-duration curve (lower) and when reaction of degeneration was present (upper). Galvanic response obtained as indicated by arrows. Faradic response only with electrical excitability as indicated by lower curve.

information concerning the state of the nerve, but have not solved the problem of concluding at an early date whether the nerve is completely severed or if there is regeneration. The galvanic-faradic tests for reaction of degeneration have been used for years but perhaps the limitations have not always been recognized. Since this phenomenon was described by Erb, in 1867, more complete studies have been made on electrical excitability of muscles. It has been shown that to obtain a contraction the stimulating current must have a definite strength (volts) and duration (milliseconds). There is a known relationship such that for every given voltage there must be a certain duration of current flow; the greater the voltage the less time it must be applied to obtain a liminal contraction. This relationship may be plotted in the form of a graph known as a strength-duration curve. A normal curve is illustrated in Figure 1, giving a fairly accurate visualization of the electrical excitability of the muscle tested. With degeneration of the motor nerve to a muscle there are changes in electrical excitability as is well known. The strength and duration of stimulating currents must be increased to procure a contraction and this decreased excitability is reflected in the curve as shown in Figure 1. When testing with galvanic and faradic currents one is actually determining two points on this excitability curve. The galvanic stimulation corresponds to the longest duration of stimulus and the faradic to a much shorter stimulation for each impulse. The

voltage is not measured with faradic stimulation and noted only roughly with galvanic and in both instances is limited by the tolerance of the patient as high voltages are painful. The reason a faradic

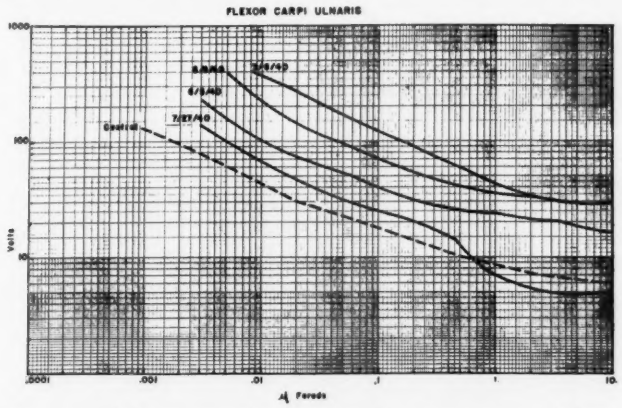


FIG. 2. Voltage-capacity curves in ulnar nerve injury showing normal control and progressive improvement in affected muscle over a four months' period.

response is not obtained in denervated muscle is shown diagrammatically in Figure 1 for with the voltage tolerated there is not sufficient duration to produce a contraction. Determining chronaxy also amounts to observing accurately one arbitrary point on the strength-duration curve from which deductions as to excitability are made. It, therefore, becomes apparent that determining the whole strength-duration curve is a more complete and accurate measure of electrical excitability.

In selected cases we have used this method of observation to follow the course of nerve regeneration or to determine the extent of nerve injury. The technic employed consisted of using either a small bore hypodermic needle as stimulating electrode or a small zinc disc with electrode paste. A large dispersive electrode was attached to the opposite pole of the stimulating machine. The end point was taken as the just visible contraction of the muscle as indicated by movement of the needle or skin over the muscle with varying strengths of stimuli. The stimulator was designed by Grass, of the Harvard Medical School, and allowed the use of stimulating currents varying in capacity from 10–.001 microfarads and in voltage up to 400 volts. Suitable series and shunt resistances were coupled in the stimulating circuit to minimize the effect of varying skin resistances. The condensers of larger capacities are known to discharge over a longer period of time and this relation of capacity to time can be expressed by a simple mathematical formula converting capacity readings

to milliseconds. In these observations, however, only the capacities were recorded and plotted against the voltage on logarithmic paper forming a voltage-capacity curve comparable to those described by

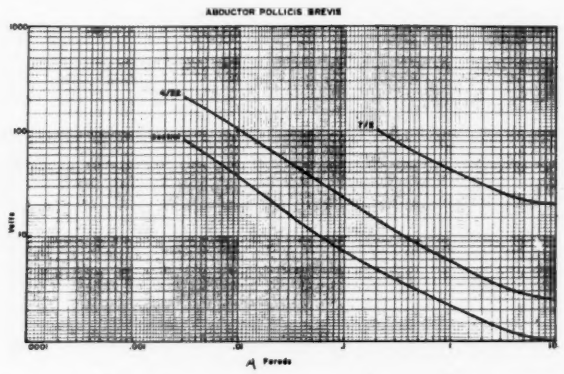


FIG. 3. Voltage-capacity curves in median nerve injury showing progressive loss of excitability.

Rosenblueth[6] in his recent studies on degeneration of mammalian muscle. Observations were made in ascending and descending order with control readings on comparable unaffected muscles of the opposite extremity when possible.

A typical normal voltage-capacity curve is shown in Figure 2. The changes effected by injury to the motor nerve are also illustrated in the same figure. This case is that of a patient with neurofibroma in the region of the elbow, but not attached to the ulnar nerve. This tumor was removed surgically with some difficulty due to local hemorrhage. Postoperatively there was complete ulnar nerve paralysis and it was not known whether this was due to inadvertent injury from instruments or to damage by hematoma. Electrograms were first done four months postoperatively at which time there was clinically no sign of regeneration either motor or sensory. Sensory testing was complicated by excessive scar tissue of the forearm in relation to the tumor and was of little value. The results of the electrical tests are illustrated and show the gradual improvement in excitability in the flexor carpi ulnaris muscle before this could be determined clinically, thus allaying fears that the nerve might have been severed.

In another case of a boy who fell on a milk bottle severing tendons and nerves in the wrist and hand the opposite results were obtained. The abductor pollicis brevis and opponens muscles were affected and these muscles were tested by the same method for signs of spontaneous regeneration. The voltage-capacity curves are shown in Figure 3

and demonstrate progressive loss of excitability from which it was concluded that spontaneous regeneration could not be expected and an operation was performed.

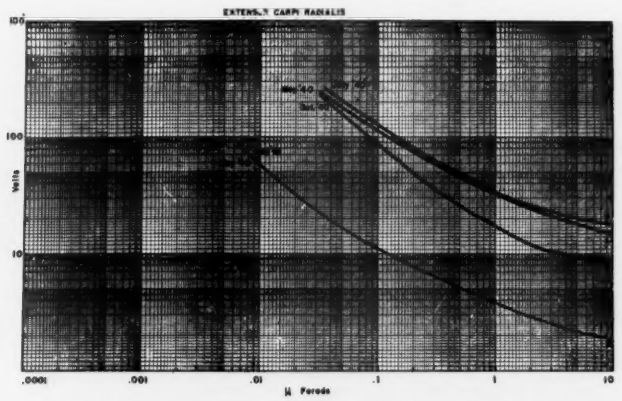


FIG. 4. Voltage-capacity curve in radial nerve injury. Curve D shows the normal control, also return to normal after one year of the affected muscle. Curves A, B and C show the course of electrical excitability in the interim.

The next case is that of a man who received a stab wound in the middle of his upper arm with resultant infection and sudden hemorrhage two weeks later for which he was operated upon. The hemorrhage was controlled but there was noted later complete radial and median nerve paralysis, these structures not having been identified at the time of operation. The problem here was to decide whether or not the nerves in question might spontaneously regenerate. The arm was splinted, the patient received physical therapy and the excitability of the denervated muscles was tested from time to time. The results appear in Figures 4 and 5. The flexor carpi radialis and extensor carpi radialis muscles were examined and interestingly the first sign of improvement was noted on the day he was scheduled to enter the hospital for exploration. This procedure was cancelled and he has gone on to complete recovery of function.

Another case was referred to this clinic for question of exploration and possible suture of the radial nerve. He had received a stab wound above the elbow five months previously with complete radial nerve paralysis and no clinical signs of regeneration. Electrical examinations were done and one month later, when repeated, showed the first signs of regeneration other than some tingling in the thumb, indicating that regeneration might be expected to occur spontaneously. (Fig. 6.)

We wish to point out and emphasize that a single examination of the electrical excitability of a muscle will not indicate the state of the nerve in question. For five to seven days after even complete sever-

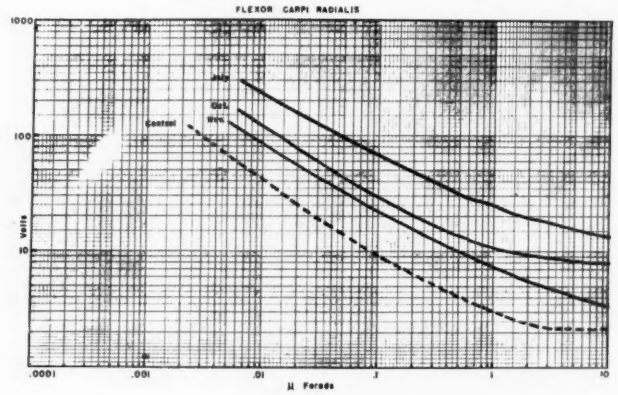


FIG. 5. Voltage-capacity curves in median nerve injury showing progressive spontaneous improvement in electrical excitability.

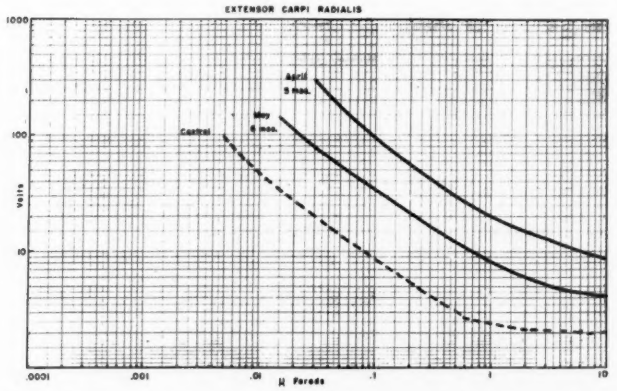


FIG. 6. Spontaneous regeneration in radial nerve injury as indicated by approach to normal of the voltage-capacity curve.

ance of a nerve the electrical excitability of the muscle is normal. There then develops a progressive loss of excitability which is manifested by loss of faradic response and changes in the strength-duration curves as shown. The first signs of regeneration as indicated by electrical examination of the muscle do not appear for an appreciable length of time, months usually, whether one tests with the faradic coil or by the method used here. Repeated determination of voltage-capacity curves has given us some quantitative information as to the extent of nerve injury, whether partial or complete and also in special cases has revealed signs of regeneration before noted other-

wise. We have the impression that sensory regeneration precedes electrical improvement, but no statistical evidence. Tinel's sign has been unreliable in a small number of cases. In the majority of cases on record careful sensory examination has been the most reliable early sign of regeneration when such a test was possible. When sensory findings were unreliable, voltage-capacity curves have been very helpful in making an early prognosis. Galvanic-faradic testing is useful in differentiating hysterical from organic paralysis and in rough quantitative estimates of the degree of injury, but of little value in detecting early regeneration.

We conclude that a quantitative method of determining electrical excitability of denervated muscle such as the voltage-capacity curve is of value in judging the extent of nerve injury, in detecting early signs of regeneration and in following the course of repair. It may also prove of assistance as an objective test evaluating the usefulness of various therapeutic procedures particularly physical agents such as heat, massage and electrical stimulation.

## TECHNIC

We have neither originated nor employed any departure from standard surgical practice. We believe strongly in a careful physical examination to determine the exact amount of damage done in any fresh injury. If we see a patient within a few hours after the accident, we hope his wound has not been contaminated further by well meaning bystanders and even doctors.

One detail that we lay particular emphasis upon is the liberal use of normal saline solution. While operating upon a hand recently injured it is not uncommon to use ten or twelve liters, constantly running a stream of it into the wound. Even in an old case the incision is frequently flushed with saline and only wet sponges are used. An anatomical dissection is performed, the nerve ends isolated and carefully approximated with fine silk, care being taken that the stitches traverse only the epineurium. The question of funicular apposition is frequently raised. It seems reasonable to suppose that axones will provide better function if they are allowed to progress down their proper funiculus, and that poor function despite regeneration may be attributable to their not finding the proper pathway. However, in Bell's palsy, though there is no division of the nerve and consequently no loss of funicular apposition, regeneration is frequently only partial. At all events, the impossibility of correctly aligning the funiculi at nerve suture is very apparent at operation,

and we suggest only that rotation be eliminated as much as possible.

If the wound has been contaminated and sepsis appears likely, we still advise nerve suture; for even if the worst occurs and the suture is a failure, the ends will more likely be in apposition and secondary suture facilitated.

If the injury is an old one, the nerve ends are freed from the surrounding scar tissue and sectioned with a sharp knife until normal appearing nerve tissue is demonstrated, thus disposing of scar tissue and neuromas before suturing. If retraction of the nerve ends has been excessive or if too much damaged nerve has had to be sacrificed to make suture without undue tension impossible, even with utilization of joint mobility, one must do what one can to attain more length. This can usually be accomplished in the ulnar nerve by freeing and transposing the nerve anterior to the medial epicondyle. The median and radial nerves cannot be extended as far, but considerable length may be gained by freeing the nerve throughout a large part of its course. The most spectacular success we have attained in this manner was in the case of a twenty-one year old girl who four years before coming to us had severed both the median and ulnar nerves in the midhumerus region. No attempt at nerve repair had ever been made. At operation the proximal ends of both nerves had retracted seven inches so that they lay under the pectoralis major muscle. Freeing them for a considerable distance with gentle traction, supplied enough length so that they could be sutured with the arm in extreme adduction. Three years later she had regenerated sensation to all but the tips of her fingers and has enough motor regeneration to play the piano.

We have lately attempted to gain length by planning a multistaged procedure. This entails suturing the proximal and distal neuromas together under rather more tension than would be desirable in a nerve suture, and, if in the forearm, with the wrist in acute flexion. During the succeeding two to six weeks, the wrist is gradually extended, thus stretching the nerve. When this has been accomplished, the neuromas can be excised and the ends approximated with the wrist again in a flexed position. This operation has been performed too recently to allow of our judging of its success. We have had no experience with the fibrin nerve sutures as advocated by Young and Medawar.[5]

All arms with sutured nerves are placed in plaster splints postoperatively. These are designed to fulfill two purposes: The first is

to ensure that no added tension will be placed on the suture line, and the second is to prevent excessive stretching of denervated muscles. We follow in large part the principles laid down by Harmer[2] on the subject of splinting.

Usually the original cast is not removed for two weeks, at which time the wound is inspected. By the end of three or four weeks the primary function of the cast has been fulfilled and the task is now one of rehabilitation. Splinting to protect the paralyzed muscles must be continued, but the position of function is now assumed and the patient sent to the occupational and physiotherapists. We believe that these two play a large part in whatever success we attain. Our patients for the most part co-operate and many return several days a week for months at a time in order to receive treatment. They are meanwhile followed at regular intervals in the Hand Clinic, where progress is noted and suggestions made for further treatment.

## SUMMARY AND CONCLUSION

This report summarizes the results in 110 injured ulnar, median and radial nerves, treated at the Massachusetts General Hospital during the years 1931 to 1940. Eighty-four and five-tenth per cent were considered to have shown satisfactory end results based on arbitrary criteria. Ulnar nerves successfully regenerated in 88 per cent, median in 82 per cent and radial in 78 per cent of their total numbers.

It could not be established that the age of the patient, the presence of infection in wounds or the time interval between injury and treatment had any bearing materially upon the eventual outcome. The average rate of regeneration lay between 1 and 1.5 mm. a day.

Nerve injuries associated with fractures are discussed separately and are shown to regenerate successfully in 95.7 per cent of their total number.

A new technic of determining electrical excitability in peripheral nerves is described and methods of treatment are outlined.

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## DISCUSSION

ARTHUR L. WATKINS (Boston, Mass.): It is frequently difficult to tell the degree of nerve damage, or at an early date whether or not regeneration may be expected to occur spontaneously, in spite of good clinical examination as for sensory impairment or motor loss, atrophy, and so forth.

This is particularly true of radial nerve injuries in which it is known that sensory losses may come after sensory return, maybe after motor return, in combined median nerve and radial nerve injuries in which the sensory areas overlap, in fascial nerve injuries in which the sensory loss is not present and in some cases in which sensory tests are not reliable.

Frequently, electrical examinations are made to give additional information, particularly galvanic and faradic testing. This has not been entirely successful. Ever since 1867, when Erb described the reaction of regeneration, there has been more learned with electrical excitability of nerves and muscles.

It has been shown that in order to get response to electrical stimulation a certain voltage of current is necessary, and also a certain type of stimulus. Therefore, you must have both strength and duration for any individual stimulus in order to get muscular contraction.

If you take stimulation with varying currents in varying durations, you can plot curves which will give an example or show just what the electrical excitability of the muscle in question is in a fairly accurate way. As you increase the voltage and lessen the time, the shape of the curve goes up. When reaction to regeneration is present, there are changes in this curve. More voltage is required and also a greater length of duration of stimulation is needed for each individual voltage required.

In other words, the curve tends to shift. The relation between these changes in the faradic and galvanic test is obtained, while with your long duration you get a response when reaction to degeneration is present. With faradic stimulation, you have a much shorter time interval of stimulation for each impulse as it comes in, and the voltage is limited by the apparatus and the tolerance of the patient, so that with faradic current you would only have an area in here where you can get a response. If you do not get a response, there is an alteration in the excitability.

We have used in selected cases a means of testing this excitability by an apparatus with which you can measure the discharges of condensers and also the voltage by meters, by using a needle electrode or occasionally surface electrodes as a stimulating electrode, and large dispersive electrodes with the other poles.

He had a case of an ulnar nerve injury of an individual who had a tumor in the region of the elbow which was removed, and there was a good deal of hemorrhage. Following this, it was noticed he had an ulnar

nerve paralysis. The question arose whether or not the nerve had been cut, or whether spontaneous regeneration might here be expected.

Excitability tests were done at varying intervals. Sensory tests could not be done, because of the extensive scar tissue over the forearm. This was our only means of telling at an early date whether or not degeneration might occur.

A couple of months after the patient was first seen, there was an improvement noted as less voltage was noted, indicating probably regeneration would recur without the need of operation.

In a similar case, but in a median nerve, there was no improvement, therefore, operation was performed.

I wish to point out, however, that even with these tests a definite length of time must be waited before signs of regeneration occur electrically. It may be a matter of months, depending on the length of distance from the site of injury to the muscle being examined. In general, the sensory tests are probably the earliest signs of regeneration. Where they are not possible or unsatisfactory, we believe that this method of testing is helpful.

F. J. Tees (Montreal, Quebec): I am delighted to see the excellent results that Dr. Hamlin and Dr. Marble reported in the care of the medians and ulnars. During the last year of the First World War, we had admitted to the Granville Canadian Special Hospital, where I was working, some 500 patients with peripheral nerve injuries. We made it a rule, of course, not to attempt treatment of these patients until at least three months had elapsed after healing, and we found that of that number, only 150 were referred for operation, which meant that a great many of these war nerve wounds would recover spontaneously.

Of the 150, roughly one-half came for suture and one-half for a neurolysis.

I have a very firm belief that the important thing in nerve suture is to get end-to-end apposition, and I think Henry Marble's seven-inch gap is perfectly wonderful. We managed to close a four-inch gap in an ulnar nerve in the forearm and thought that was pretty good.

One method that I think is of importance when a large gap is found is to do the two-stage operation; that is, first of all to free the nerve up and down, approximate the bulbs, and close up; then at a later stage do the final end-to-end suture.

What I think is perhaps the most important thing of all in attempting to do the nerve suture is to avoid rotation of the nerve. Those who have had experience in nerve suture will realize how even in the atrophied end of a nerve you can make out the little pattern of the nerve bundles corresponding with the nerve bundles at the peripheral end, and one should make every attempt to get those two patterns to correspond.

Our experience was totally different from that reported by Dr. Hamlin, because our recoveries in the muscular spiral or radial nerve were immensely better than in the medians and in the ulnars.

We thought that the reason why the radial nerve recovered so much better was because it has just a gross movement to do, that is, it is just responsible for the dorsal flexion of the wrist and fingers, while the ulnar nerve is asked to do such opposite things as separating fingers and bringing them together. If the least amount of torsion is present, one can easily see how that is disturbed.

We did have one rather interesting case which I wish to report. Our cases were always admitted to the care of the neurologist. This man was admitted with a paralysis of the deltoid muscle and he had a small wound at the back of his shoulder. Colonel Mackay, who was in charge of the medical side, had an *x*-ray taken which shows a little square piece of shell fragment lying behind the head of the humerus, and more as a joke he referred the case to the surgical side for, as he said, "suture of the circumflex."

We reflected the lower border of the deltoid and located that little piece of shell fragment lying on the bone. We were luckily able to find the proximal end of the circumflex and the two distal ends. The circumflex is not much bigger than the piece of lead in a lead pencil, but we were able to draw the ends together and left it at that.

To our amazement, the man had a definite recovery within thirty days after the operation, which leads me to think that the nerve makes a pretty good try to find its way down to the distal ends.

# SPIRAL AND OBLIQUE FRACTURES OF THE TIBIA*

## A METHOD OF TREATMENT

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A BETTER understanding of skeletal traction coupled with the use of the fluoroscope in the closed reduction of fractures has lead to a decrease in the indications for open operation. However, with the proper surgical technic the risk associated with open reduction is so slight that one should not hesitate to operate in order to bring about those conditions necessary for rapid, complete healing and early return of function.

We do not wish to reopen the controversy regarding the selection of cases for open operation at this time. On the Stanford Surgical Service at the San Francisco Hospital we consider the danger of delayed union and nonunion following spiral and certain oblique fractures of the tibia so frequent that prompt open operation is justified. It is believed that the accurate reduction and rigid fixation attained at operation will assure early union provided early weight bearing is instituted. It seems necessary to add that such a position must be qualified according to organization, personnel, equipment and patient.

It is common knowledge that prolonged immobilization of a fracture often leads to atrophy of the neighboring musculature and fixation of joints. This explains current enthusiasm in regard to the early mobilization of joints and the early introduction of physiotherapy. It is, however, impossible to maintain complete fixation of a fracture of most long bones and at the same time institute early physiotherapy. The removal of fixation apparatus for the introduction of motion and massage results in delayed union more often than is generally recognized. On the other hand, we have come to recognize that even though it is necessary to maintain complete immobilization of joints in the vicinity of a fracture, one may avoid impairment of motion in the joints and atrophy of nearby musculature by institut-

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ing early active use and weight bearing. Early weight bearing seems also to maintain the circulatory status of the part and to speed up calcification of the callus, leading to early solid bony union.

It has long been recognized that use of wire is a simple and efficient means of achieving accurate fixation in the open reduction of fractures, and that its use necessitates the introduction of a minimum of foreign material which might retard union. The disadvantages, however, have been that silver or other nonoxidizing wire was not strong enough to maintain fixation, particularly in that type in which there is no weight bearing surface at the site of fracture. Steel wire of suitable strength had the disadvantage of oxidation with reaction about it.

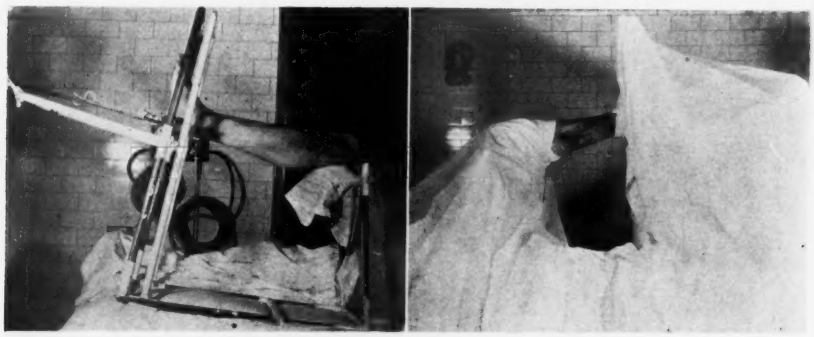
The introduction of rustless steel wire for the fixation of fractures soon after the use of stainless steel in the manufacture of surgical instruments seems to have overcome these disadvantages and because of its tensile strength and durability allows us to return to a simple means of internal fixation. It is important, however, to emphasize that in all types and forms of internal fixation the actual fixation of the fracture is maintained through an external splint. It was not until the advent of the nonpadded plaster cast that it became possible, even with the combination of internal and external splinting, to immobilize completely certain types of fractures to the point of weight bearing.

With these considerations in mind we have attempted to devise a means of treating spiral fractures of the tibia which will allow first, accurate reposition of the fragments, second, complete fixation of the fracture and third, early weight bearing on the fractured limb. The method of treatment outlined here cannot be called a new treatment. It is the combination of several principles previously suggested which has enabled us to work out a satisfactory method of treatment for spiral and certain oblique fractures of the tibia.

## DETAILS OF OPERATION

Under spinal anesthesia a Mathews' pin is inserted through the os calcis and a properly fitting stirrup so applied as to avoid any motion of the pin in its longitudinal axis. The limb is then placed on a Böhler frame (Fig. 1A) so that the knee is flexed at right angles to the long axis of the body, with the buttock resting firmly on the operating table. A small pillow is placed in the popliteal space to prevent pressure necrosis as traction is applied to the limb through the Mathews' pin. Sufficient traction is then applied to maintain the limb

rigidly in the Böhler frame and to overcome as much shortening as possible. It is possible at this stage of the procedure to correct any rotatory deformity of the lower limb. With the leg remaining in the



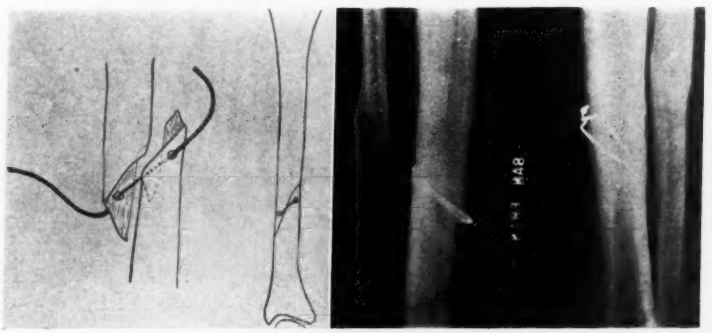
A B

FIG. 1. A, position of limb in Böhler frame with skeletal traction in os calcis. B, limb draped in frame for operation.

frame the skin in the operative field is prepared, first by cleansing with tap water followed by the application of lime and soda which is removed with water, alcohol and ether. The skin in the immediate operative field is then prepared with tincture of merthiolate. The leg is draped for operation, leaving only that small area of the skin exposed which constitutes the operative field. (Fig. 1B.) A straight longitudinal incision is made over the anterior medial aspect of the limb at the fracture site. The skin edges are then covered with towels held in place by Michel clips. Hemostasis is not necessary because the pressure on the limb in the popliteal space against the transverse supporting bar of the Böhler frame is sufficient to act as a tourniquet. The bone is exposed by retracting the margins of the wound with hook retractors. The subcutaneous tissues separate from the periosteum without difficulty and with very little associated tissue damage.

As a rule one will find that most of the deformity, i.e., shortening and rotation, has been reduced by the preoperative manipulation in the Böhler frame. It is interesting to note how frequently one finds shreds of periosteum overlapping the spiral component of the fracture, intervention of soft parts, and, if operation has been delayed, how often one is unable to reduce the fracture completely because of the intervention of partially organized blood clots between the fragments. It is almost always possible to obtain a perfect reduction by very simple manipulation in the frame. It is imperative that the fractures be so perfectly reduced that there can be no motion at

the site of fracture, otherwise the repeated traumatization of subsequent weight bearing gives rise to recurring hyperemia and consequent decalcification.



A B

FIG. 2. A, schematic drawing of method of placing stainless steel wire. B, roentgen examination following reduction with wire in place.

With the fragments in perfect apposition, they are held in place by a lion-jaw clamp and drill holes are made at an angle through the fragments crossing the spiral component of the fracture in such a fashion that the uppermost hole is in the proximal point of the distal fragment and the lowermost hole in the distal point of the proximal fragment. It is important, as will be shown later, that these drill holes be so placed. A rustless steel wire is then threaded through these drill holes. If perfect apposition of the fragments has not already been obtained it is a simple matter at this point, by using the steel wire as a guide, to force the fragments into position.

It is not necessary that the wire be so placed that it will prevent rotation, lengthening, or angulation of the fragments, for the application of skin-tight plaster gives us sufficient external fixation to prevent subsequent occurrence of these deformities; however, it is absolutely essential that the wire be so applied and of sufficient strength to prevent shortening. It is for this reason that we use rustless steel wire.

By placing the wire so that the upper portion of the loop is in the proximal end of the distal fragment and the lower portion of the loop in the distal end of the proximal fragment, we are able to form a steel sling at the fracture site which, with each attempt of nature to cause shortening, forces the fragments into more complete approximation. (Fig. 2A and 2B.) The wire is drawn up and twisted over the surface of the bone and its twisted ends hammered down against the bone so that they will not cause subsequent soft tissue pressure necrosis.

The advantage of having the limb suspended in the Böhler frame becomes apparent at this point. With the fragments fixed in place with a single piece of steel wire the reduction is maintained. The fixation which comes with perfect reduction is of sufficient strength to maintain the position of the fragments with the aid of the Böhler frame. The handling of the limb, ordinarily accompanying the application of plaster, is avoided. The normal physiological pull of the muscles has been overcome by the right-angle position of the leg and also by the traction in the frame. If necessary, the operation and subsequent application of plaster may be completed alone without the aid of assistants, the reduction being maintained throughout subsequent procedures, by the Böhler frame.

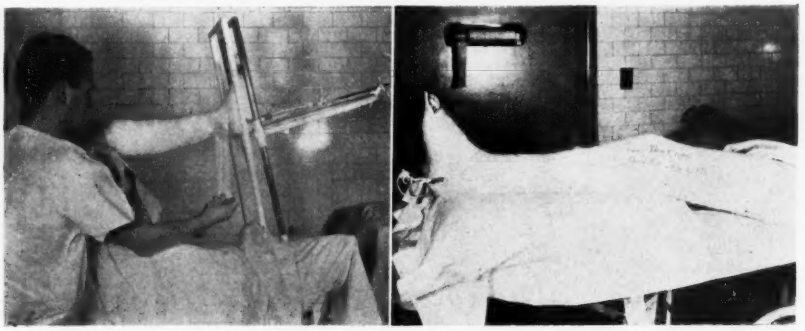
The wound is closed by approximating the subcutaneous tissues with a few interrupted catgut sutures and the skin with interrupted black silk sutures. A small tincture of benzoin dressing is placed over the wound and held in place by a few turns of sterile sheet wadding. It is imperative that this dressing be as slight as possible in order not to interfere with the application of the skin-tight plaster.

The leg is now ready for the application of the plaster cast. A long posterior plaster splint is prepared of 4″ bandage of sufficient length to extend from the tip of the toes to the junction of the upper and middle thirds of the thigh. This splint is firmly molded to the posterior aspect of the leg and the plantar surface of the foot by the application of a circular flannel bandage. We do not direct the turns of the flannel about the leg but allow them to follow their "natural course" so that no constricting areas will result. It is important that a narrow bandage be used and that it be so applied that the flat surface is always flush with the skin; this necessitates frequent cutting but in the end the application is smooth. (Fig. 3A.)

The fixation of the posterior plaster splint in this manner is carried out from the tip of the toes to the popliteal space. With the limb still in the Böhler frame a circular plaster bandage is then applied to the lower limb. Particular care is taken to mold the plaster to the leg in order to avoid subsequent pressure. It is advisable to mold the plaster about the ends of the Mathews' pin in order that the plaster will completely fix the pin in place. During the time of application of plaster to the lower leg one must take care that the part of the posterior plaster splint which extends from the popliteal space to the thigh be kept moist by constant kneading and re-wetting.

As soon as the plaster on the lower limb is set the limb is removed from the Böhler frame and the knee extended. The upper part of the

posterior plaster splint is molded into the popliteal space and onto the posterior aspect of the thigh and circular plaster extended above the knee joint to the junction of the upper and middle thirds of the



A B

FIG. 3. A, application of posterior splint and cast to lower leg in frame. B, long leg cast after extension of the knee.

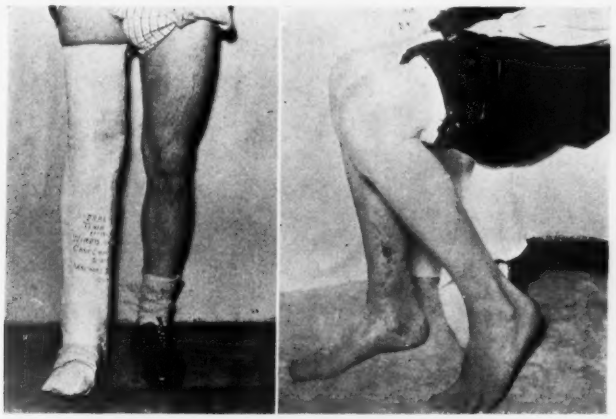
thigh. (Fig. 3B.) When the plaster is set, before it has dried, it is split throughout its entire length, along the dorsal surface to allow for postoperative swelling. In cutting the plaster away from the dorsum of the toes, when the cast is trimmed, one should be certain that the plaster on the dorsum of the foot remains intact up to the webs of the toes. This will prevent painful herniation due to postoperative swelling of the loose areolar tissue at this point. It should be noted that in every patient upon whom we have operated in the Böhler frame, the circulation, as indicated by the color of the toes, has returned immediately following removal of the limb from the frame

## AFTER-TREATMENT

During the first forty-eight hours following operation it is well to keep the limb elevated in bed. A postoperative anteroposterior and lateral film is taken as soon as possible following operation. If the fragments are in perfect apposition, the Mathews' pin is removed from the heel. The cast remains in place, with the limb at complete rest for two weeks following operation when it is removed.

During these two weeks of fixation the patient is encouraged to exercise the quadriceps and the flexors and extensors of the toes within the cast. At the time of removal one usually finds that there has been considerable loosening of the cast because of the reduction in the swelling of the limb. By this time the wound is completely healed and the silk sutures may be removed. It will also be noted that as a general rule there is sufficient fixation at the point of fracture to allow the patient to raise the extended limb from the bed

without support. A nonpadded plaster cast is now applied including the lower leg and the thigh to the junction of its upper and middle thirds. A walking iron is applied to the cast and from this day on the



A B

FIG. 4. A, long leg walking cast applied ten days after open reduction. B, knee joint flexion to 90 degrees immediately after removal of walking cast.

patient is not only allowed but encouraged to bear full weight on the affected limb within the limits of pain. (Fig. 4A.) If the cast has been properly applied and if the internal fixation with wire has been properly performed, the patient is soon able to bear full weight without pain and usually with the aid of only one crutch. It is possible for this patient to return to his work providing his occupation is such that it does not necessitate standing. The walking cast remains in place for six weeks. If at any time during these six weeks plaster becomes loose, it is removed and re-applied.

Complete bony union of the fracture is as a rule obtained at the end of this period. In case there is any question of bony union at the time of removal of the walking cast a new cast should be applied immediately. It will be noted that upon removal of the walking cast there is, as a rule, only slight atrophy of the musculature of the limb and that motion in the ankle and knee joints is only slightly limited. (Fig. 4B.) It is only at this stage of the treatment that active physiotherapy, i.e., massage, active and passive motion, should be instituted. The return of complete function with the use of these methods is very prompt.

## MATERIAL

A total of 132 spiral fractures of the tibia comprise this group. Seventy-four were treated according to the method described,

twenty were treated by means of skeletal traction above and below the fracture site with fixation in a plaster cast, eighteen were treated by means of a single traction pin through the os calcis and fixation in a cast, and eighteen by simple reduction and a long-leg plaster cast. Seventy-two per cent of the patients were males. The ages ranged from three years to eighty-two years, the average being 36.7 years. None of the patients in the younger age group were treated by open operation. In children there is rarely an associated fracture of the fibula and consequently very little if any displacement of the fragments of the tibia. This group is best treated by simple immobilization. The youngest patient operated upon was fifteen years of age.

In the entire group there were seven compound fractures, two of which were compounded from the inside out. This is not difficult to understand when one realizes that the mechanism of injury in this type of fracture is almost always one of indirect violence. The two fractures which were compounded from within were the result of weight bearing immediately following injury. The remaining five resulted from external violence.

The interval of time between the accident causing the injury and admission to the hospital varied from a few hours to twenty-four days; the majority, however, entered the hospital on the day of the accident. An effort was made, provided the condition of the patient and the fractured limb warranted it, to institute local treatment at once.

In that group of seventy-four patients treated by open reduction whenever possible, the operation was undertaken as an emergency procedure immediately following admission. In a small group of patients, operation was delayed because of the patient's general condition or because of open wounds in the immediate vicinity of the fracture line. The blebs and blisters and the excessive swelling so commonly noted following this type of fracture were not considered contraindication to immediate operation inasmuch as the contents of blebs are sterile and swelling subsides very rapidly following the rigid fixation and accurate reduction associated with open operation.

Those patients treated other than by open operation were so treated because the tissues locally would not warrant open operation, because the patient fell into the younger age group, or because the patient came in on a service which wished to try more conservative means of treatment. This segregation of patients has fortunately served the good purpose of allowing a comparison of end results.

## RESULTS

In the seventy-four patients treated by open reduction and wiring according to the method described, all operative wounds healed *per primam* with the exception of two. In these two infection occurred on the fifth postoperative day. The wounds were opened and packed with vaseline gauze without disturbing the immobilization. In both cases healing was retarded; however, in both healing took place within five months. In the patients operated upon, the period of immobilization in plaster was from eight to twelve weeks, and the average total period of disability fourteen weeks from the date of operation. In this group there was one case of nonunion. This occurred in a thirty-seven-year old female who was discharged from the follow-up clinic sixty-seven days after operation with "good union" and "a good functional result." She returned two years later with a nonunion at the site of fracture. After removal of the steel wire and drilling of the fracture site, prompt healing occurred. It was necessary to remove the wire in two additional cases because of local irritation. These wires were improperly placed at the time of operation.

In the remaining sixty-eight patients treated by closed reduction, even though they include eighteen cases in which the patients were fourteen years of age or younger, the average period of immobilization in plaster was five months and the average total period of disability seven months. In this group there were eleven cases of nonunion, three of which occurred in patients treated by means of simple casts following reduction, and eight of which occurred following the use of two pins, one above and one below the fracture site. We are of the opinion that this method not only does not allow weight bearing at the fracture site, but often maintains distraction, which is a frequent cause of nonunion.

## SUMMARY

1. A method of treating spiral and certain oblique fractures of the tibia is presented.

2. A summary of seventy-four cases in which the patients were treated by this method is presented, together with sixty-eight cases in which other methods of treatment were used.

3. A comparison of the end results of treatment has been made.

DISCUSSION

KELLOGG SPEED (Chicago, Ill.): This is an important contribution with a well grounded mechanical background. To discuss Dr. Mathewson's paper I would like to mention a point lightly touched by him in the opening paragraph when he said that with proper surgical technic the risk associated with open reduction is so slight that one should not hesitate to operate in order to bring about these conditions necessary for rapid complete healing and early return of function. From the standpoint of his activities and surroundings this is so; it may be so for every member of this association, but in spite of the rapid spread of well taught surgical technice in university hospitals we must admit that over 90 per cent of all fractures occurring in this country are still handled by practitioners. These men doing only occasional surgery cannot be expected to have either highly developed surgical facilities nor the ready-at-hand surgical technic and ability to perform open operations on the tibia. Have we reached the point in hospital development and control of men practicing surgery where we wish to encourage this practice nationally?

When and if such fractures can be transported within a few hours to the hands of a qualified surgeon, then possibly no one could object to open reduction of the difficult oblique and spiral fractures. They fall into a class of too easy secondary displacement even when treated with bone transfixion followed by skeletal traction and plaster embedding although the primary reduction may have appeared eminently satisfactory. I agree that exact reposition may control and yet assure callus effort and that thoughtless physiotherapy may endanger the result. Early weight bearing likewise may ensure a follow through to mature callus formation but I am not acquainted with any proof that it speeds it up in physiological time. With weight bearing axial replacement of the bone must be guaranteed along with the apposition of the fractured surfaces and if the external fixation does not meet this demand, the bending and possible rotation at the weak fracture sight will prolong healing. Hence the firm fixation by the internal splint plus the nonpadded, glove-fitting plaster encasement in combination may hold definitely.

In the details of the operative technic I wonder at the necessity for the lime and soda application removed by water, alcohol and ether. Dr. Mathewson uses tap water but does not mention soap in the primary cleansing. In many clinics soap and water after shaving followed by 80 per cent alcohol to remove some of the superficial water is considered adequate preparation. Perhaps the thoroughness of any method of preparation is the secret of its success, but it should remain as simple and cheap as possible. We do not find that tinctures of any antiseptics will penetrate more than one layer of superficial epithelial cells once they are engorged and water swollen.

In spite of the effort by this method to avoid shrinkage of muscle and soft parts, we see that a secondary cast for ambulatory purposes is an essential factor. In that regard the method may fall short of an ideal procedure. Many of us may, however, adopt this ingenious fixation as an easy-to-get, inexpensive substitute for metal plates and the paraphernalia required in their application. The results appear highly satisfactory and may be compared in time and quality with those obtained by surgeons using rigid internal fixation by plates alone, disregarding external splint support. As the controversy for and against external fixation after internal splinting ages we seem reduced to the conclusion that we are still dealing with the virtue of concentrated attention of the man giving treatment rather than any one definate method of treatment.

R. Arnold Griswold (Louisville, Ky.): Dr. Mathewson was kind enough to send me a copy of his paper. There are a great many things in it with which I agree and a few with which I heartily disagree.

I do not think that we have to do open operations on the great majority of spiral oblique fractures of the tibia and fibia. I think we can put a great many into plaster and walk them very early without internal or external fixation, except for the plaster cast. Some more of them we can put into position with pins above and below. I should also like to state that, in that connection, pins above and below the fracture can be used not only for distraction or traction and countertraction of the fragments, but they can be used for control in all directions and, if necessary for compression of the fracture. Distraction, of course, is one of the dangers of powerful mechanical methods, and it does produce delayed union.

The principal thing that I admire in Dr. Mathewson's paper is a very simple principle which applies to the open operation on all bones, whether it is the arm, the forearm, the femur, the leg, or the spine; that is, an operation on any bone should be carried out under traction and with the bone in the position in which it is going to be fixed after operation is complete. With this method you do not have to put the leg or arm into the hands of an assistant to hold while you are putting on a cast. This disturbs the relationship and increases the stresses on your plate, or your wire, while you are applying external fixation.

I think the most important principle that Dr. Mathewson has brought out is that of operating upon the fracture in traction, and I should say, in the position in which it is to be fixed afterward. He operates with a flexed knee. I should prefer to do it in traction with the knee straight, in the position in which it is to be fixed after the operation is complete.

Clay Ray Murray (New York City): It can be said that the ideal way to treat a fracture is to wish the fragments into place, and hold them there by moral suasion and let the patient go right on about his business.

The degree of efficacy of any method of fracture treatment is to be gauged by how nearly it approaches this ideal. It is based on the principle that if you cannot do good, for Heaven's sake, don't do harm.

This method approaches that ideal. The sling principle of preventing the deformity of over-riding, and by limiting that deformity during weight bearing, of actually encouraging accurate approximation of the surfaces, is ingenious, logical and sound. The only criticism which I have to make of this procedure is this: It might be epitomized in this phrase, "Why send a boy to do a man's errand?"

It is perfectly possible to fix bone fragments today by the proper observance of sound mechanical principles, so rigidly that active motion of all the joints involved, plus early weight bearing, can be instituted without external fixation, in other words, a nearer approach to sending the patient about his business.

The principles involved in this procedure are absolutely correct; but if one is going to expose the patient to what is commonly branded the terrific risk of an open reduction of a fracture, if one is going to put fixation elements into the bone, I cannot understand why the fixation apparatus must consist of something which will prevent deformity *provided you tie the extremity up in plaster.*

The procedure, if one is going to operate and if one is going to fix the fracture, is not logical if it requires in addition external mobilization. The claim is made that because of this method of fixation, it is possible to institute at least partial function, that is, of weight bearing. There are methods just as safe if you are going to do an open reduction and fixation, which can be used, which will install full function rather than partial function. I, therefore, approve of this procedure in principle, but from my own standpoint I believe that once you get in, if you are going to fix the fracture you might just as well fix it adequately, enough to be able to leave off the external plaster.

I have been told very emphatically by numerous people that the function of the lower extremity is weight bearing, and that if you immobilize a joint for from six to twelve weeks (if I did not misunderstand the terms of this paper), five minutes after the plaster is off they have function of the knee and ankle joint. I find myself unable to take any patient out of plaster after twelve weeks and get his knee to a right angle if it has been at 180 degrees for twelve weeks.

Now, the knee of this particular patient unquestionably was at right angles in five minutes. I do not know how much he enjoyed it. But if you take the run-of-the-mill patient and put him in plaster with a knee straight for twelve weeks, it has been my experience that motion of the knee is restored very gradually.

Not that you cannot eventually get function of the knee. But I object strenuously to talking of a patient in terms of eventual function. These

patients have wives and children, the vast majority of them. The question as to whether it takes three months to get their function back or three weeks is an important proposition, not to the doctor but to the patient.

I believe that as long as you are going to operate, and as long as you are going to practice fixation, then you ought to practice the type of fixation which allows you to continue not partial but as nearly complete function as possible.

In addition this man required a pin through his os calcis. It is not without risk. I think, taking things by and large, the method is sound, but it goes only part way.

HERBERT M. BERGAMINI (New York City): I was not aware that I was to enter into any discussion until this morning, so I do not feel fully prepared to say anything.

Dr. Mathewson came to me this noon and briefly outlined his paper. All I can do is to repeat what Dr. Magnuson said in regard to Dr. Murray's paper—he was sorry he could not put up an argument. I rather fall in line with all that Dr. Mathewson has presented.

His rather uncommon sense and not so-called common sense use of mechanical principles is worthy of the attention of all of us. It is quite similar to a method we have been using for just this type of spiral-like fracture in the lower extremity in which we use quite similar mechanical principles in putting not a plate but a wire (stainless steel No. 22 gauge) barrel-like hoop about the fracture site.

Then we follow, I might say, the most uncommon sense principle of distracting slightly these spiral oblique fractures on the principle of the inclined planes, tying the encircling loop snugly, so that, as the inclined planes or the spiral fracture becomes non-distracted, the wire hoop becomes snugger and accomplishes much the same purpose that Dr. Mathewson accomplishes by his reverse oblique insertion of those wires. Dr. Mathewson's method is a very clever procedure.

In concluding I feel the urge to tell this story which is circulating around Washington: Quite recently a telegram arrived at the White House addressed to no one less than the late Honorable Woodrow Wilson. This is alleged to have arrived last week. It read: "Mr. Wilson, don't look now, but we think somebody is following you." I think somebody is following me.

CARLETON MATHEWSON, JR. (closing): I have not very much to say. Seeing is believing. It is true that many of these joints will not flex to 90 degrees immediately after removal of the cast, although this man's did, and he was sixty-five years old. However, a large majority of them will if they bear weight on their fracture as they are instructed to do during the period of healing.

We know that this occurs in the knee joint and in the ankle joint, regardless of what Dr. Murray has to say, because we have observed it in a large number of patients. I might say if we were going to Dr. Murray

to have your fracture treated, it would probably be a good idea to have it plated. If you came to me, it would probably be a good idea to have it wired. If you go to Dr. Griswold, it would probably be a good idea to put pins in it.

I was hurried in my review. We had, at the same time that we treated these fractures, an equal number of patients on the other side of the ward, being treated by double pins and by plates. The number of non-unions and infections were much greater in this group.

I have a patient in the hospital now who walked for fifteen years by means of a plate, before it became infected and was removed. He now has ununited fracture. We have all seen these cases, and that is why we object to the use of plates.

I object to two-pin traction because a large percentage of people who use this method will distract the fragments, not in the sense that they are pulled apart in the longitudinal axis, but rather they will maintain rotatory distraction which leads to delayed union and non-union. In many of these cases periosteum has fallen between the ends of the bone, so that even though they are reduced they will not heal.

I would like to thank these gentlemen for discussing the paper.

# CONVALESCENT CARE OF PATIENTS WITH FRACTURES*

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NEW YORK, NEW YORK

A PATIENT with a fracture is commonly convalescent from the moment his fracture has been reduced and the method of fixation decided upon and effected. He enters the hospital a broken man, not a sick man, physically or mentally. It behooves us to see that he does not become ill during his convalescence. The less he is put in the same category with the sick patient, and rather treated as a person who was perfectly well an instant before the accident and expects to stay well, the shorter will be the period in which he needs convalescent care. The solution of the problem for the patient with a fracture and the general hospital is not more beds of the ordinary convalescent type. These do not keep a well man well. His institutional convalescent care, however, concerns the general hospital, the out-patient department and the organized convalescent institution.

As a general hospital occupant, this type of patient is too often conditioned to become an invalid during his stay. Frequently he requires prolonged care to recover from his hospitalization rather than from his injury. A young man has done heavy labor in construction work for several years. He is a superb physical specimen, proud of his ability to lift more than any other man in the gang, proud of the wife and youngster at home and of the pay check he brings in each week. Suddenly a cave in occurs pinning his thigh between rocks, which causes a fractured femur. Can we justly place this man in the same group as one recovering from a severe illness? Rather we must try to keep these young, finely trained muscles and this carefree brain in as good a condition for six to twelve months as they were two minutes before the accident occurred. This does not mean lying in bed for weeks gazing at the ceiling, except during the periods when an attractive attendant serves his food and bathes him. He begins to worry about funds, the family, his injury, his job. Gradually he softens physically and mentally. The punch is gone. This

* Presented before the American Association for the Surgery of Trauma, Seigniory Club, P.Q., May 30, 1941.

hospital life is rather comfortable anyway. Let someone else worry about his family; he is not going back to work until he is absolutely fit. Beside he has a good case against the company, didn't his lawyer say so? If we are not careful, even with a perfect surgical result, our man is liable not to return to his work for three or four years, if ever. Let us not be a party to producing unemployment. This is not convalescence from a fractured femur, but from a hospital stay, too often spent under conditions far more luxurious than those to which he has ever been accustomed. Our major effort in the early convalescent care of patients with fractures should be made from the point of view of prevention of the need of convalescence from "hospitalitis."

Special wards for fractures help greatly. It is not well for the man with a fracture to be in the same bed for three months, while on each side of him one patient after another with acute surgical conditions come in for ten to fourteen days and then go their way. It produces a feeling of frustration as he quickly becomes the oldest inhabitant of the ward. In a fracture ward he will encounter different stages of similar lesions—one man learning to use a walking caliper, another just wrestling with crutches, one being congratulated by his fellows on his first time out of bed in several weeks, another on having his traction wire removed, etc. These men are all playing the same type of game and they encourage and train one another. The new patient, meeting a proposition for the first time about which he knows nothing, rapidly falls into the routine of a fracture ward, becomes interested in the progress of the others and looks forward to his being able to do these things himself as soon as possible. Further, he is a well man among well people. Years ago it was customary to see a plaster spica applied, and then, as far as the visiting staff was concerned, the patient was passed over until the time arrived for removing the plaster. This is somewhat less frequent than formerly. Much harm to the patient results and this is another valid reason for insisting on a fracture ward. Place a doctor in charge who is really interested in fractures and you will see things begin to move. If your beds for acute surgical cases are clogged up with fracture patients, you may find that, while your visiting staff is greatly interested in abdominal work, no one is taking responsibility for making certain that the patient with a fracture is having the advantage of the most up-to-date and speedy care.

Early physical therapy to the injured part, commenced on the day of admission, is a most important part of convalescent care. We

cannot take space to go into this here. But there is much which can be called physical therapy, that should be supervised by doctors and nurses rather than technicians. Take, for example, the case in which plaster has been applied to the forearm and hand in a Colles' fracture. If applied properly, it extends to the metacarpophalangeal joints only, so that all fingers can be moved completely. Too often no one thinks to tell the patient to move his fingers. Weeks later a physical therapist works hard to gain recovery of a function which would never have been lost, if someone had insisted on the patient moving his fingers many times a day from the first day on.

At Beekman Hospital we have found class exercises of great value in the fracture ward. Because one leg is injured there is no excuse for allowing the muscles of the neck, back and three other extremities to deteriorate and greatly prolong the convalescence. Suppose on getting out of bed a patient will have to use crutches. Would he not prefer to have two strong arms and one strong leg to support him? Each afternoon one of our physical therapy technicians comes into the fracture ward, turns on a phonograph to march time and leads the men in simple calisthenics as they lie in bed or sit in a chair. All uninjured parts, or those not actually immobilized, are exercised by the whole ward together, with the technician actually instructing and leading—neck, back and the four extremities in segments. It was difficult at first with men who had never done such a thing. But once started it became a simple routine, since the new admission was ashamed not to play the game as he saw his neighbors doing. The men look forward to it now and there is no doubt that it has helped the morale of the ward as well as its physical status.

The social service department has a large opportunity in convalescent care while the patient is still in a bed on an acute surgical ward. Probably the patient had no neurosis at the time of injury, at least not a sufficient one to keep him from working. Every effort must be used against his developing one during convalescence. What are his home conditions? What are the means of support of his family? Exactly what did his work consist of? Is there the probability that he will be able to do precisely similar work? If not, with the type of mentality he has, what work could he adapt himself to? Does his employer want him back and can he expect an opening when he is ready to return? Is his family of the type which will baby him when he returns home and make him worse? If his injuries are severe and it is unlikely that he can return to a similar place in industry, is he a man who wishes to work, or will

he be satisfied to remain a cripple? Does he believe society owes him and his family a living, whether working or not?

The social service status has to be investigated and put into writing during the first few days after injury. No neurosis has been established then. This is the time to survey the problem as thoroughly as possible so that adjustments to his environment may be suggested before the problem really arises or becomes fixed in the man's mind. If we let the man who has always been a good worker become a social service problem, have we not much to answer for if we did not try to appreciate the gravity and extent of our problem in the first few days after injury?

Many persons seem to do excellently while hospitalized, but their whole mental attitude apparently changes shortly after discharge. Is it the constant solicitude of their family? Is it contact with an attorney? Is it the effect of a compensation board hearing? At any rate, we should urge the social service department to do all it can in the early days to fortify the reaction of the patient against the effect of these contacts. We must accept a certain responsibility for allowing a well man to develop into a partial or complete invalid while convalescing under our care. We have no right to treat the injured part only and stop there.

Convalescent care in the out-patient department is a serious problem. In many instances the patient is seen by a different doctor than attended him in the hospital, or even by a different doctor each day. The patient often comes to question whether anyone is really interested in his injury. Here again the social service department can accomplish much by continuing the work which it started in the hospital.

The treatment often tends to be routine, e.g., "physical therapy three times a week," with a check up by the doctor every one, two to four weeks. Physical therapy can only help the patient to help himself. Many patients are never told that their half hour two or three times a week is but a minor part of their convalescent care. They must be shown definite forms of exercise and urged to do these literally hundreds of times a day. If these can be purposeful occupations instead of mere calisthenics, they are much more effective.

The usual convalescent institution means little in the treatment of fractures. To the city patient it means a vacation in the country and little more. It is questionable whether he is helped by mingling with other types of patients at these institutions. The patient who had an acute surgical condition will return to his normal life sooner

and his actual working parts have probably not been affected. The same is true of the patient with an acute medical condition. The patient with a fracture is liable to develop a feeling of inferiority in comparison. It is a question whether the patient with a chronic medical condition will return to active life, and his association with the patient who has suffered a fracture may lower the latter's morale and make him think he is an invalid also. The same idea holds for association with the patient who has cancer or with one who represents a chronic orthopedic problem.

The patient who has sustained a fracture needs work therapy, not a vacation, but a hardening process. The usual convalescent institution is not conducive to this. Work should be started in the hospital. Ways and means should be devised to keep his mind and body occupied from the start. He should not be treated as a star boarder but as a perfectly well man except for one cracked-up part. If it is brought to the nurses' attention and properly supervised, the patient can help with many things in ward work without disturbing the morale.

Occupational therapy should be introduced much more widely in general hospitals. There are several excellent schools training persons to teach this. The great difficulty is to keep it from developing into a routine rather than using one's imagination to make the best adaptation for the individual patient. Doctors in general cannot know how to do this, but they should recognize its value, know when it is well done and back it enthusiastically. Occupational therapy is many times more valuable than the usual types of physical therapy in these patients. Even without a trained instructor and a shop, much can be done in a simple way if some one is interested in doing it.

I question gravely whether the usual convalescent institution should be used for patients with fractures and whether they may often suffer more harm than any good which ensues. At the same time I believe the ideal fracture treatment would be to institutionalize the patient from the time of injury until he returns to his usual work, or to another job for which he has been rehabilitated. This does not mean that he sleeps there or necessarily eats there. It would mean economy to all concerned if there was real supervision. At present such an arrangement is practically nonexistent.

It would mean that a well man coming to a general hospital with a fracture would not be treated as if he were ill, but as a convalescent from the start. He would be taught how to use all joints and muscles in the region of immobilization, commencing on the first day. He

would be started immediately on general exercise to preserve the musculature which he brought with him. He would be given a job to do while in bed, which would occupy body and mind and make him feel he was still a part of a moving world. As soon as he was out of bed, he would be taught some form of occupational therapy similar, if possible, to what he did before he was hurt. As soon as he is fit for discharge from the hospital, he would be an ambulatory patient, if his home conditions could possibly warrant it. If not, we should arrange for institutions where the injured are by themselves and where everyone gets work therapy. This should also be true of our out-patient departments. The patients with fractures should be gathered into those institutions where they can receive work therapy. This should be daily and for an increasing time up to a full working day. At present the ambulatory patient receives the least supervision at just the time when guidance means the most to his future economic life.

There are a few rehabilitation clinics in this country and they are doing an excellent job. But they rarely see a patient until many months after injury, and frequently only when there is a question as to how much of the disability is physical and how much functional. We need many more of these clinics, but I believe that, except in the permanently crippling injury requiring a change of occupation, the convalescent care of patients with fractures could be much better handled with work therapy from the day of general hospital admission with institutionalized supervision until again ready to work. We are wasting a tremendous amount of money and man power by treating a broken bone and letting a well man get sick physically and mentally while under our care. Then after the damage is done, we spend months, years or a lifetime trying to bring him back to normal. The development of institutions adequately manned to furnish real work therapy is an urgent need in the proper care of the tremendous volume of injured persons.

## DISCUSSION

FRANK D. DICKSON (Kansas City, Mo.): I think this paper of Dr. Kennedy's is an extremely timely one. We are gathered here and have been listening to methods of treatment as far as the fracture itself is concerned, and we are learning of more and more methods all the time. There is, however, great danger that we will become so preoccupied with the actual setting of the fracture and its local treatment that we will forget, as Dr. Kennedy has pointed out, about the human being with whom we are dealing.

I think there is nothing costing industry more money than the unfavorable mental attitude which the injured are so likely to acquire for just the reasons Dr. Kennedy has given. He has, as usual, covered his subject so splendidly that I do not think I could add much to it in the way of discussion.

I agree with him thoroughly, of course, as you all do, that segregation of the injured or fracture cases is of primary importance, and that your physical therapy should be started early and not late. By "physical therapy," I think we should understand that we do not mean merely putting on lights, which seems to be the most general physical therapy today. We mean physical therapy.

Certainly if adequate immobilization of the fractured bone is one of the fundamentals of fracture treatment, then keeping the joints adjacent to that fracture completely mobilized is almost as fundamentally important. That is where physical therapy comes in.

Occupational therapy is splendid. I believe the best occupational therapy is getting a man back to some kind of work. We find that those industrial groups who will permit you to send a man back to work, even if it is not back at the old job, just to get him back to work get better results than when the man is not accepted for work until ready for full duty. Under the former circumstances the man will get back at his old job sooner than the one in whom peculiar quirks in his mental makeup are allowed to develop.

Dr. Kennedy did not tell us how to avoid just one important thing, that is, how to keep the lawyer away from the man. He did not tell us that, and that is what I should like to know. Until the man is so favorably impressed mentally with his progress it is dangerous to allow the legal aspects to enter in. I would like then to know how to keep the lawyer away from him.

I do believe we have got to exercise a very definite interest and supervision of these men, as you say, Dr. Kennedy, until they are back at work. They are your patients until they are back on the job.

A. William Reggio (Boston, Mass.): Sometimes there are disadvantages in being at the end of the discussion when the speaker has done such a beautiful job on a subject which is extremely important, and the first discusser has kicked the remaining props out from underneath you.

I do feel very strongly just as Dr. Kennedy and Dr. Dickson have said, that the rehabilitation of the patient by means of physical and occupational therapy is of the utmost importance. One trouble is that many of the doctors who want to get their patients back at work do not know how to get them back. They do not know enough about physical therapy or occupational therapy. If I am wrong, correct me, please.

We all should go to those departments and learn for ourselves how it is being done. Then we can help those patients ourselves more intelligently, and see more clearly what is to be accomplished.

There are four big hurdles that have to be taken in getting these people back to work: There is the question of supra-orbital stenosis on the part of the patient, which is a very important factor. They do not understand what it is all about.

Then, of course, there is "compensitis," which is a very difficult disease to treat except with some paper that has writing on it. Then the thing that must be instilled into those patients—and the fellow to do it is the doctor who is in charge of the case—is the will to get well so that they will co-operate. Practically every patient that we see whom we want to get back onto the job should be told that 85 per cent of the success depends on his own effort. We can do a certain amount, about 15 per cent, but the rest the patient must do himself.

Then, the physical therapist and the occupational therapist must work more closely hand-in-hand than they do. At present, there is still a little rivalry between the two types of treatment, whereas it ought to be hand-in-glove.

At the Massachusetts General Hospital where we have a Physical Therapy Department and an Occupational Therapy Department now, the Physical Therapy Department in the past six months had ninety-nine cases, seventy-two of which were fractures of the arms and hands and twenty-one were fractures of the legs. Fifty-four of them went to the Occupational Therapy Department in co-operation.

You can get somewhere if everybody works together, but the doctor in charge of the case must keep hold of the reins and keep on steering that patient. He cannot merely refer him to the department, no matter how good a department it is, because *that* patient knows *his* doctor, and pays more attention to what *his* doctor says than to what the other department may say.

I want to see Dr. Kennedy's musical exercises sometime. I can see him swinging from balkan frame to balkan frame, teaching the patients how to do it. It takes a lot of organizing and you must have the funds to carry out the work.

As Dr. Kennedy has covered the ground so thoroughly this is about all I can say. I am very pleased to have been given the opportunity to discuss this paper which is on a subject much more important than is frequently realized.

# SPINAL CORD INJURIES*

## ANALYSIS OF SIX CASES SHOWING SUBARACHNOID BLOCK

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IT has been common practice to perform laminectomy upon patients with acute compression injuries of the spinal cord in which there was an obstruction of the subarachnoid space as shown by the Queckenstedt test. The purpose of the laminectomy in most instances has been to relieve pressure on the cord, supposedly arising from edema which followed the trauma. It has been theorized that the alleged edema produced impairment of circulation of the cord with resulting progressive damage. We have been unable to find any case in our records in which we believed laminectomy had served a useful purpose in cases of this type.

Four years ago, it was decided to study carefully those cases with compression injuries of the spinal cord with subarachnoid obstruction who came under our observation. Six such cases have been studied. This paper will present observations made on these six patients which present strong evidence that laminectomy is not indicated in the acute stages of injuries of this type. Cases with bony deformity or with compound wounds present a different problem and are not to be discussed in this paper.

### CASE REPORTS

CASE 1. E. M., a white male, age forty-one, was admitted to the Good Samaritan Hospital on August 7, 1939, with a compression fracture of the sixth cervical vertebra sustained in an auto accident. He was transported seventy miles to Cincinnati, arriving three hours after the injury. There was complete motor and sensory paralysis below the second rib and of the ulnar surface of both forearms and hands. There was also retention of urine and complete absence of reflex activity below the level of the lesion.

*X*-rays showed a compression fracture of the sixth cervical vertebra without dislocation. A lumbar puncture released blood tinged fluid and showed a complete obstruction to the Queckenstedt test.

The physician who had seen him immediately after the accident was confident that there was some sensory function preserved in the right leg at that time. On the basis of this, a laminectomy was immediately done.

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The laminae of the fifth, sixth and seventh cervical vertebrae were removed. The lamina of sixth cervical vertebra was badly comminuted. The dura was intact. There was no intraspinal clot. The cord at the level of the disc between the sixth and seventh cervical vertebrae was ecchymotic and swollen. On palpation, the cord was found to be markedly softened and pulpy. Cerebrospinal fluid was obtained from above by jugular compression. A catheter was passed downward without meeting resistance. The dura was left open.

As soon as the patient was removed from the operating table, the lumbar puncture was repeated. There was still a complete obstruction of the subarachnoid space. The block persisted for two days, but on the morning of the third day the dynamics were normal. He had had no manipulation during the interval, except that required for the care of his skin. This patient died at home three months afterward of urinary sepsis. There was no autopsy.

*Comment.* This case was significant, for the obstruction of the subarachnoid space persisted for two days after laminectomy but cleared up on the third day.

Case II. C. H., a white male, age twenty-one was admitted to the Good Samaritan Hospital on July 4, 1938, after having been injured in a diving accident three hours before we saw him. He had evidence of a complete lesion below the seventh cervical dermatome, and *x*-rays showed a fracture dislocation of the sixth on the seventh cervical vertebra. There was a complete obstruction of the subarachnoid space as shown by the Queckenstedt test. Skeletal traction was applied by means of Crutchfield tongs with fifteen pounds over one pulley. The following morning, fourteen hours after the accident, there was still subarachnoid obstruction, though the block could be overcome by prolonged jugular compression. A laminectomy was then done, and the cord decompressed. Immediately after operation, the block was still complete. Forty-eight hours after operation, the Queckenstedt test was normal. Death occurred on the sixth day as a result of respiratory failure.

*Comment.* It is interesting that the block should have cleared up on the third day in this case as well as in Case I.

Case III. A negro, male, age thirty, fell down an elevator shaft, and was admitted to St. Elizabeth's Hospital, Covington, Kentucky, on December 30, 1938, with a fracture dislocation of the fifth on the sixth dorsal vertebra, and with evidence of a complete cord lesion below this level. We saw him twenty-four hours later. *X*-rays showed moderate compression of the body of the fifty dorsal vertebral, with an oblique fracture of the body and slight lateral displacement. The laminae were fractured, and they appeared to be pushed into the canal. There was a complete obstruction as shown by

the Queckenstedt test. A laminectomy was done because of the depressed laminae. At operation the laminae were not found to be depressed to any appreciable degree. The cord at the level of the injury was complete pulp.

It was planned to do a Queckenstedt test immediately after operation, but no sterile monometer was available so it was deferred until the next day. At that time, there was no obstruction. This patient succumbed on the thirty-fourth postoperative day with general sepsis from decubitus ulcers. There was no autopsy.

*Comment.* In this instance, we credit the operation with possibly relieving the obstruction, but it should be remembered that forty-eight hours elapsed before this was established.

In the first two cases, the subarachnoid block did not disappear as shown by the Queckenstedt test until the third day. In the third case, which occurred in the dorsal area, the block disappeared within twenty-four hours after operation was done. It will be recalled that this was forty-eight hours after the injury had taken place. We were of the opinion that the block had subsided spontaneously, perhaps contributed to in part by the removal of the posterior wall.

In each of these cases, there was complete absence of normal cord structure at the level of the injury. This has been previously mentioned by many authors, particularly Thompson[1] and Coleman.[2] In such cases, the apparent normal contour of the cord so often seen after removal of the posterior wall is, in fact, nothing more than complete disintegration of tissue held in molded form by a limiting pia which is not torn. The first two cases cited, we believe, show conclusively that laminectomy does not always serve its purpose of relieving obstruction of the spinal subarachnoid space in compression injuries of the cord.

Having presented these cases to show that the obstruction may not disappear immediately following laminectomy, we would like to present in brief two other case reports of patients who have had obstruction of the subarachnoid space on admission, and who have, over a period of three or four days, reestablished normal circulation of the cerebrospinal fluid although no laminectomy was done. These also had complete lesions and have shown no recovery of function.

Case iv. K. I., a white female, age twenty, was admitted to the Deaconess Hospital, Cincinnati, Ohio, on December 28, 1938, after having been injured in an automobile accident. At the time of admission, there was complete loss of function below the level of the sixth dorsal dermatome and evidence of a bony deformity of the fifth dorsal vertebra. In addition to

this, there were extensive lacerations about the scalp and face, several fractured ribs, and the patient was in profound shock. Immediately after admission, the wounds of the scalp were irrigated and closed loosely, and infusions of glucose and normal saline begun. Two transfusions of 500 cc. of citrated blood each were given, and within a few hours, the shock had been overcome.

A lumbar puncture was then done which showed a complete obstruction of the subarachnoid space as demonstrated by the Queckenstedt test. The patient's general condition made laminectomy inadvisable; and since her clinical findings indicated a complete physiological lesion of the cord, it was not done. The following day the lumbar puncture was repeated. The obstruction was still present. On this day, we were able to obtain *x*-rays of her spine, which showed a fracture dislocation of the fifth dorsal vertebra with some lateral displacement of the superior fragments. There was also an oblique fracture line through the body of the fifth. There was considerable agitation by a member of her family, who was a physician, to have a laminectomy done at this stage, and requested a consultation by Dr. John Caldwell of Cincinnati. He agreed with me that the laminectomy was futile and incurred the risk of the patient's life due to extensive associated injuries. On the third day, the lumbar puncture was repeated and it was noted that the obstruction was not complete. On the fourth day she was placed in a bed over an extension frame, but before doing so a lumbar puncture was again done with a completely normal response to the Queckenstedt test. This patient is alive but has had no return of function.

*Comment.* This case is recorded because of the spontaneous disappearance of the subarachnoid block in this instance, taking place on the fourth day, whereas in two of the three cases cited previously, the obstruction persisted until the third day even though laminectomy was done.

In this case, as in certain others, we have been criticized by friends and relatives for not operating, and have been told by several prominent neurosurgeons that the family and the patient often times accept a hopeless prognosis more resignedly after operation has been done. We have not considered the emotions of family and friends as a worthy indication for surgery.

CASE V. A white female, age twenty-two, was admitted to St. Mary's Hospital on June 5, 1940, with a compression fracture of the sixth cervical vertebra without dislocation. The bony alignment was good. There was, however, complete sensory and motor paralysis below this level. The tendon jerks at the knees and ankles were absent. There was a subarachnoid block. This patient was thought to have a complete transverse physiological lesion of the cord, and it was believed that operation was not

justified. Crutchfield tongs were applied with fifteen pounds of traction over a single pulley. Within twenty-four hours the block of the subarachnoid space had disappeared.

*Comment.* The relief of obstruction in this case may have been affected in part by the traction, but certainly the degree of bony deformity was not great. Whatever the cause, whether it was spontaneous or the result of traction or both, swelling of the cord subsided to the extent that the circulation of the cerebrospinal fluid returned to normal within twenty-four hours after the injury without laminectomy. This patient is alive but has had no return of function.

CASE VI. M. W., a white female, age fifty-seven, was admitted to Christ Hospital on March 8, 1940. At the time of admission, this patient was suffering with considerable pain in her neck with radiation of pain and numbness into the ulnar distribution of her hands. She was unable to move her legs and had retention of urine. There was marked reduction of all forms of sensory function below the third rib, and in some areas of the legs there was complete anesthesia. A lumbar puncture done shortly after admission showed complete obstruction of the subarachnoid space. She was placed at bed rest without traction because the family would not authorize this procedure. By the following morning, her condition was considerably improved. She was then able to move the toes slightly but could not lift her legs from the bed. There was normal sensory function above the umbilicus, and numerous patches on the legs in which sensation appeared normal. There was still retention of urine. A lumbar puncture was not done on this day.

By the third day, her clinical improvement was marked. She could raise her legs from the bed and had normal sensation. There was still a block of the subarachnoid space as shown by the Queckenstedt test.

At this stage she was complaining of pain in her neck with radiation of pain into her hands. It had been suggested prior to this that Crutchfield tongs be applied to the skull for traction, but her son objected to the idea, and it was not carried out. However, after considerable discussion, consent was obtained, and traction with fifteen pounds over a single pulley was begun on the fourth day. Within a few moments after this was instituted, the pain in her neck and arms disappeared, and the following morning, she had almost normal function in her legs, though she still had some hyperesthesia in the ulnar distribution of her hands. The lumbar puncture on this date showed a normal response to the Queckenstedt test.

*Comment.* Here again it is possible that the skeletal traction may have affected the cerebrospinal fluid dynamics. It is significant,

however, that the patient showed progressive recovery of function despite the presence of a subarachnoid block.

## SUMMARY AND CONCLUSIONS

We have presented the data from six cases of major compression injuries of the spinal cord, and have shown that laminectomy does not in all cases relieve pressure on the cord, insofar as it can be demonstrated by the Queckenstedt test. It has been shown that obstruction of the subarachnoid space may disappear spontaneously, and that the cerebrospinal fluid dynamics may return to normal in patients not operated upon in about the same period of time as in those upon whom laminectomy was done. It is already well known that correction of bony deformities may relieve pressure upon the cord, and in two of our cases, this may have been accomplished by means of skeletal traction. In one case, however, the obstruction was definitely relieved spontaneously before any manipulative treatment.

To justify laminectomy as a method of treatment in acute spinal cord injuries, one must assume that several conditions prevail: First, that as a result of pressure on the cord, progressive damage is being produced or recovery is being delayed because of amnoxia of that portion of the cord; second, one must assume that the operation accomplishes its purpose of relieving the pressure; third, that relief of pressure will not occur spontaneously; and finally, one must assume that this is the best method available for the purpose desired.

It must be granted that edema may cause impairment of circulation of the cord although the excellent clinicopathological work of Thompson[1] associated with his experimental data indicate that the maximum damage to the spinal cord occurs at the time of impact and is not progressive. There was a slight difference of opinion between Allen[3] and Thompson[1] concerning the lesions produced by compression injuries to the cord. Allen[3] believed that there was extravasation of blood into the cord substance, and that this produced progressive damage from edema over a period of four hours at which time the maximum destruction was reached. He did not believe that this could be altered by taking away the posterior wall of the spinal canal and opening the dura, but that it could be arrested only if operation were done within the first four hours, the posterior commissure split and the intramedullary blood and necrotic tissue evacuated.

The Queckenstedt test is, of course, not an infallible means for determining the presence of pressure upon the cord, for it has been demonstrated that the response to jugular compression will be normal as long as the lumen of the subarachnoid space is not less than the bore of the needle used (Poppen and Hurxthal).[4] Consequently, it is possible for local pressure to be present without obstructing the canal. Fragments of bone and protrusions of intervertebral discs might produce local injury that would require laminectomy. In addition to this, there are cases on record that have shown progressive loss of function that were reversible by laminectomy. We have not encountered such a case. We realize that the result of the Queckenstedt test must be correlated with the clinical findings in making any decision for surgery.

We are convinced from the observations of this small group of six cases that the result of the Queckenstedt test should not influence one appreciably in selecting cases for laminectomy. We would consider laminectomy indicated in compression injuries of the cord only if there was an incomplete lesion and the patient were showing progressive loss of function, and the loss of function could not be arrested by closed manipulation.

While the immediate observations of this paper are derived from the six cases referred to, the opinions expressed above have necessarily been influenced by the experience of one of us (F. H. M.) in the treatment of twenty-eight other cases with acute spinal cord injuries without obstruction during the past four years, and a much larger group observed over a six-year period prior to 1937.

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## DISCUSSION

Arthur R. Elvidge (Montreal, Quebec): I feel quite unable to discuss this paper in the place of Dr. Penfield. However, being an obedient servant I have come anyway. Dr. Mayfield is a friend of mine, and I am sure he believes that I am a friend of his, and at the same time, being friends, I am sure he does not expect me to agree with everything that he has said.

However, it seems to me that the points that he has brought up are extremely important (we know they are, of course). He stressed the question of spinal block and has this fine series of cases which is a very able work.

I have not had much time to read over the paper. I think the question of spinal block, however, really amounts to the consideration of a single sign. When one is deciding whether to do a laminectomy or not, it seems to me that the result of the jugular compression test is just one sign to be added to the other findings at the time, that is, the clinical, neurological findings, and perhaps particularly the *x*-ray findings.

He has been talking principally about the question of edema of the spinal cord, and whether laminectomy will unblock the subarachnoid space which has been blocked due to edema. I think cases that are blocked merely due to edema of the spinal chord without much else must be on the rare side. It seems to me that, as a rule, there is generally a more complicated lesion than that, and I hesitate to say what I would do if I had a case with a spinal block if I knew that there was only edema present, but I do not see how you can determine that beforehand.

I would like to know whether he opened the dura or the pia.

If a case is partially paralyzed and has a complete block, such a case still has function, and there is the possibility that function below the level may be increased with decompression.

On the other hand, if one is sure that the spinal lesion is complete and is going to be permanently complete, of course there is no real reason to do any operation. On the other hand, it is very difficult to prove that before hand, so that if I were asked to handle a case, I think I should want to have the neurological examination, the lumbar puncture, and, particularly, very good *x*-rays, because it seems to me that a great deal depends on the *x*-ray findings, the type of fracture and the type of dislocation present.

There are so many cases in which bony fragments are depressed; for instance, fragments from one laminal arch may be thrust beneath the laminal arch above, and it is very hard to see that even in the *x*-rays.

I think one of the advantages of exploration is to be sure that such is not the case, and if it is, to relieve it surgically. I think there are many advantages to exploration if there is sufficient indication present. For example, one can see exactly what the lesion is, remove any depressed fragments, and help perhaps to reduce the dislocation if it has not been done before by some closed method.

One can inspect the cord and have some idea of the prognosis by inspecting the cord. If any hemorrhagic cyst or fluid cyst is present, one could aspirate it from the cord. A spinal, subdural effusion is sometimes present which can be released. If there is a frank contusion of the cord, I think one can safely at times aspirate it without causing increased damage.

Then, in addition to all that, if one wishes and believes it is wise one can at the same time do a spinal fusion either with grafts from the tibia,

ribs or even with os purum, so that I think there are many advantages to an exploration; and though I think probably Dr. Mayfield may be correct in many cases, I do not think laminectomy should be laid aside too readily and in too many cases. I would prefer to call it an exploration rather than laminectomy, so as to cover the various points.

TOM OUTLAND (Harrisburg, Pa.): As a mere orthopedic surgeon, I assure you I feel very humble in attempting to discuss this problem which in the past, at least, has been regarded as a purely neurosurgical one. However, living in a community which is on the edge of the hard coal mining region and on two main highways, I, of necessity, come into contact with a considerable number of these patients.

I usually accept, as the basis for exploratory or decompression laminectomy, whichever you want to call it, the presence of a complete block or, in rare instances, without a complete block, those in which the *x*-ray shows what appears to be a depressed fracture of the lamina which I assume might be pressing insufficiently to cause a complete block.

My experience, as far as the results are concerned, has been very uniform. I have never seen a patient in my own hands (and there is little in the literature that would lead me to believe otherwise in other hands) with complete transverse lesion of the cord, show any important recovery. On the other hand, I have never failed to see one with an incomplete lesion show some or complete recovery.

The conclusion which might be drawn is that the prognosis in a given case is determined at the time of the injury, and that the subsequent treatment, assuming it was not actually harmful, had little to do with it.

I like very much the temperate tone of Dr. Mayfield's paper and, as a matter of fact, see no reason why discussion regarding this subject should be heated, since both groups—those who approve laminectomy and those who oppose it—are tarred with the same brush in that the results are very unsatisfactory.

# A METHOD FOR CLOSING A TRAUMATIC DEFECT OF A FINGER TIP

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THE hand is injured in one-third of all industrial accidents,[1] the fingers being involved in many of this group. Loss of a finger tip is not an infrequent injury and in many individuals it is a seriously disabling one. A typist, musician, electrical worker or skilled mechanic is greatly handicapped by the loss of a finger tip and further disabled by the thin, easily ulcerating, painful scar which often results after the healing of these wounds. A method of surgical treatment which will lessen the disability in these injuries, restore the part to a nearly normal condition and reduce the time of healing is worthy of consideration. In this paper there is presented a method of restoring a defect of a finger caused by accident. Only the early cases are reported, the secondary ones presenting scars of healed wounds for excision and grafting are not included.

We first used this method on April 28, 1921. A kitchen employee of the hospital had the tip of the left midfinger shaved off when he put his hand in a moving coffee grinder. Figure 1 illustrates the nature of the injury. A flap was sutured to the tip of the finger from the palm of the hand in the manner shown in Figure 2. The final result showed a finger with no disability, normal sensation in the grafted area, and scars that were scarcely visible at the tip of the finger and in the palm of the hand. Figure 3, a photograph taken in 1939 eighteen years after the accident, shows the result of operation.

Later, in 1923, one of the stenographers of the hospital slammed a door on her left midfinger. The tip of the finger was pinched off. She reported to the hospital the following morning and a graft from the palm of the hand was sutured to the defect in the finger. Again the result was good. November 6, 1926, she wrote, "The scars on both the finger and the hand are so faint now that it is hard to tell anything has been done to the finger. No one ever notices it unless I should happen to call their attention to it. I type with it all the time now and it never bothers me in the least." Figure 4, a photograph taken in 1926, shows appearance of finger two years after operation.

The method was not again used until a few years ago. Now nearly all our finger tip defects are treated by this method.

In 1926, Gatewood[2] reported a similar method which he used to

FIG. 1.

FIG. 2.

FIG. 1. A, traumatic defect at tip of index finger; B, flap raised from thenar eminence.

FIG. 2. Flap sutured to tip of index finger.

cover a defect in the palmar surface of the distal third of the finger. He mentioned the fact that at that time the Thiersch graft was the most popular method of closing these defects of the fingers and hand, but thought that the graft was not serviceable because it remained thin and adherent. He believed that full thickness grafts had too few takes except in the hands of a few surgeons. Figure 5 shows a diagram taken from Gatewood's article.

In looking through the literature for the past decade we find that these wounds are still closed by free grafts such as the Thiersch, Thiersch-Ollier (split grafts), and full thickness grafts, by tube grafts from the skin of the chest or abdomen or by sleeve or pocket grafts from the abdomen, hip or some other area. Gilcreest[3] has described an amputation of the tip of the distal phalanx in which the remaining two-thirds of the nail are preserved and all the soft parts remaining after the injury are sutured to the nail. Lauten[4] placed the finger in a pocket graft over the crest of the ilium and used a graft from the crest to restore the lost bone. With the exception of Gatewood's article, we did not find any mention of using the skin of the palm of hand as a source of the skin flap.

It has been our experience that Thiersch, split grafts and full thickness grafts do not fill the defects as adequately as the flap from the palm of the hand which carries the underlying fat. The flaps from

other parts of the body while excellent for the dorsum of the hand and fingers are of a different texture and color than the palmar skin, are more easily traumatized and do not give a good cosmetic result.

FIG. 3. E. R. Photograph taken October 27, 1939, eighteen years after accident shows result at tip of midfinger and on thenar eminence.

The objection which might be offered to taking a graft from the palm of the hand is that there is no skin to spare in this region and that the resulting scar in the palm is in itself disabling. Another objection is that in some of the older individuals, keeping the finger immobilized to the palm of the hand for two or more weeks is liable to cause contracture of the joints of the finger. Although we have not a large number of cases to report, we believe we can state fairly that if one pays attention to detail in the operation and after treatment, these complications will not occur or be serious enough to offset the good features of the method.

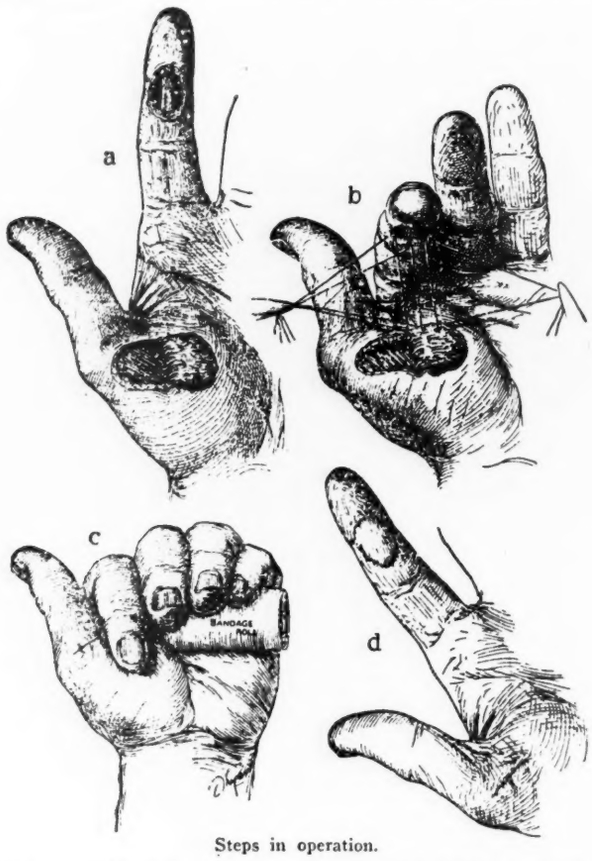
As a working rule it is considered that these wounds are contaminated up to twelve hours and that after that time infection has

already taken place. Therefore, we do not usually accept these cases for reconstructive and plastic operations after the twelve-hour period.

FIG. 4. E. C. C. Three years before this photograph was taken patient slammed door on tip of left midfinger. Graft from thenar eminence was sutured to tip of finger. Note faint scar on thenar eminence.

Most of these injuries to the finger tips occur in men who are working at the time of the accident. The fingers and hand are often covered with grease or other material with which the patient has been working. We have found that equal parts of chloride of lime and sodium bicarbonate mixed into a soft paste with water makes an excellent cleaning agent. The wound is kept covered with sterile gauze and the remaining fingers and hand are gently massaged with the mixture, after which the hand is washed with sterile water poured from a pitcher. After the hand has been dried with a sterile towel, ether and then alcohol are used, followed by tincture of iodine and alcohol, equal parts. This preparation is not allowed to enter the wound but comes up to the edges of same.

The finger is anesthetized with a 2 per cent solution of procain, the digital nerves being blocked in the proximal third of the finger. Next the wound is gently washed with pure soap and water, followed




Steps in operation.

FIG. 5. Diagram shown in Gatewood's article. (From Gatewood, *J. A. M. A.*, 87: 1479, 1926.)

by sterile normal salt solution. A débridement is then done with a sharp scalpel. All foreign material is removed with the tissue to which it is clinging and all devitalized and mangled tissue is excised so that only healthy, viable tissue remains. If the nail is missing and the nail bed badly damaged, it is completely excised. If there is a fracture at the tip of the terminal phalanx, the loose fragments are excised and the tip of the phalanx rounded off smoothly. If the digital arteries continue to bleed after the application of fine hemostats, they are ligated with triple No. 000 plain catgut with only two knots, the ligature being cut close to knot. However, we avoid as far as possible putting any catgut into the wound. During the operation the wound is bathed in a 1 per cent solution of chloramine-T. We do

not use mercury compounds because the lime and soda and tincture of iodine preparation followed by mercury antiseptics have caused skin rashes.

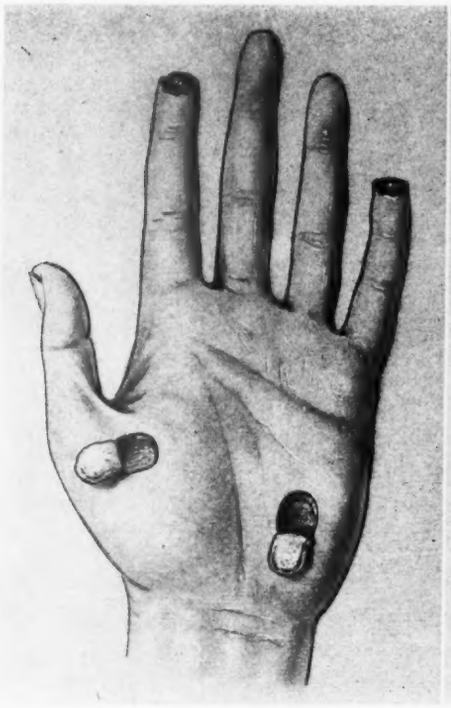


FIG. 6. 1, Pedicle laterally; 2, pedicle proximally. This illustration shows the flap raised from the thenar and hypothenar eminences. The flap avoids the creases and the mobile distal half of the palm.

FIG. 7. Shows the graft sutured to defect in finger tip. There must be no tension on sutures and no kinking in graft where this runs from graft onto finger.

The finger tip is flexed against the palm and a pattern of the defect is thus made on the skin of the thenar or hypothenar eminences. This area is next anesthetized with 2 per cent procain and the flap raised with the pedicle proximally or laterally, whichever is more convenient. (Fig. 6.) Skin flaps should not be taken in the palm of the hand distal to the thenar and hypothenar eminences. Here the skin is mobile and moves with the fingers. Also, there are important creases which incisions should not cross. The flap must be wide enough to cover the defect without tension and when raised as long as the defect. As much fat as necessary is raised with the skin. Figure 6 shows the flap raised from the palm. The finger is now approximated to the palm and the distal end of the graft is sutured to the skin between the defect and the nail, to the nail itself, or to the skin

of the dorsum of the finger depending on the nature of the wound. (Fig. 7.) The sides of the graft are sutured to the sides of the defect as far proximally as possible without tension or kinking of

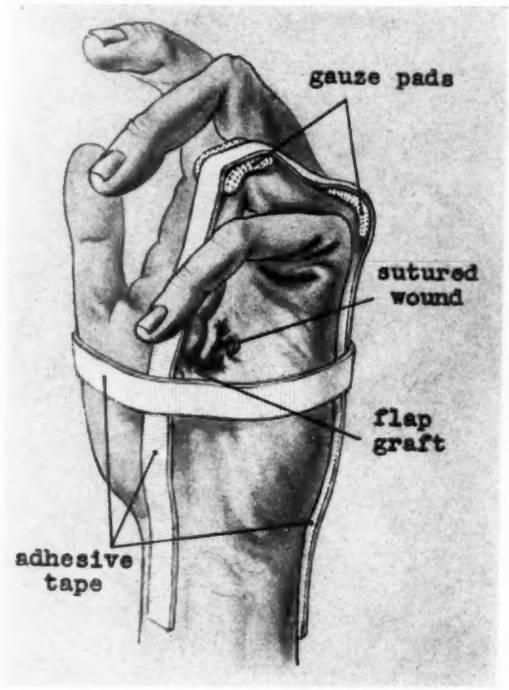



FIG. 8. Shows the suturing of graft to defect completed. The wound in palm caused by raising flap has been sutured. Adhesive tape which has been passed through the flame of an alcohol lamp has been applied as illustrated. A dressing of vaseline gauze is passed between finger and palm to cover wounds. A light layer of gauze is placed over finger and the hand bandaged. A padded board splint is applied to dorsum of hand and forearm and extremity kept elevated in an arm sling.

the graft. An assistant keeps the finger approximated to the palm until the end of the operation. Care must be taken that there is no tension on the sutures and no kink in the graft where this runs from the palm of hand onto the finger. We use horsehair sutures for most of the suturing, but an occasional fine silkworm gut suture is used where added strength is necessary. Next, the defect in the palm caused by raising the graft is sutured with light silkworm gut. These sutures must not come too close to the base or pedicle of the graft because of the danger of constriction or pressure. (Fig. 8.) A light gauze

dressing is placed over the wound. Figure 8 shows the suturing of the graft to the finger tip completed.

The finger is held in position with adhesive tape which has been

FIG. 9. T. N., age forty-three, a fisherman. About 10 P.M., October 19, 1939, left little finger was struck by a closing window, the end of finger being cut off. He entered the hospital at 1 A.M. October 20, 1939. *X*-ray films showed a crushing fracture of distal extremity of third phalanx, nail missing. On October 20, a first stage autoplasty was performed and on November 16, the second stage was done. On November 16, 1939, the patient was discharged to out-patient department, San Pedro, California.

run through the flame of an alcohol lamp. One strip of tape starts on the back of the hand and runs over finger and down onto the palm and lower forearm. A pad of gauze is placed over the knuckles where the adhesive tape passes over them in order to prevent pressure sores. The finger is further immobilized by adhesive tape running transversely across the distal third of finger and also across the first longitudinal strip. (Fig. 8.) A light pad is applied and the finger

bandaged to the hand. It is necessary to remove only the outer dressing in order to inspect the graft. Thus the graft, finger and hand may be inspected at any time without any disturbance to the opera-

A B

FIG. 10. A and B, photographs of same hand seen in Figure 9 taken November 6, 1941. Note scar on hypothenar eminence.

tive field. A basswood splint is placed over the dorsum of the hand and forearm and the extremity is kept elevated on a pillow while the patient is in bed and in an arm sling when the patient is up and about. The splint and elevation of the limb are very important in the after-treatment.

The sutures are removed about the tenth to twelfth day, the wounds carefully cleaned with ether and alcohol and the adhesive tape reapplied to the finger. In two weeks to eighteen days after the operation the graft is detached from the palm. Local anesthesia may be used again, but gas inhalation anesthesia or pentothal intravenously are frequently given. The granulation tissue at the tip of the finger and on the undersurface of the graft is excised. The skin

edges are slightly undermined and a slight amount of skin is excised around the margin of the wound. The wound in the palm of the hand is closed in a similar manner. The graft is now sutured to the remaining portion of the defect with horsehair sutures. Sometimes a rubber band drain is placed in an angle of the wound. The joints of the finger are manipulated and the finger completely extended. A light dressing is applied and the finger bandaged with the joints in slight flexion. The basswood splint is again applied and the arm kept elevated. Sometimes a moist dressing of aqueous azochloramide or chloramide-T solution is applied to the wound. Two or three days later

TABLE I

SHOWS THE NUMBER OF CASES, THE RESULTS AND DURATION OF TREATMENT

TOTAL NUMBER OF CASES – 18.

| | GOOD | FAIR | POOR |
|---|---|---|---|
| Result on finger tip | 16 | 1 | 1 |
| Result on donor site, palm of hand | 16 | 2 | — |
| Contracture of finger | One with slight non-disabling contracture but two other fingers of same hand also contracted. | Two cases rather slow in recovery of complete extension of finger. | |

Duration of Treatment: Average number of days = 43
Maximum number of days = 80
Minimum number of days = 28

the wound is dressed. It is seldom infected, but occasionally there is a collection of serum between the wound and the graft. This is irrigated away with a medicine dropper filled with aqueous azochloramide, and a few drops of a solution of azochloramide in triacetin 1–500 injected under the flap. In a few days the wound becomes dry. The same treatment may be used in the wound in the palm of the hand. In a week to ten days the joints of the finger may gradually be extended. The sutures are removed after the tenth day. After the fourteenth day the hand is cleaned and washed with soap and water. A day or two later there is a desquamation of the outer layer of the skin over the graft and a pink healthy looking skin remains. If there should be any delay in the complete extension of the joints of the

finger, this may be corrected by applying a board splint to the dorsum of the hand and forearm and placing a wide rubber band over the terminal phalanx of the finger. It is well to place a pad between the finger and the rubber band. We have not yet had any serious or disabling contractures of the joints even in our older patients.

In a few weeks sensation appears in the graft. With use of the finger irregularities in the graft and the scar tend to smooth out and later disappear, so that in many cases it is difficult to see where the graft was placed. We have not yet had any painful scars or neuromas develop.

Table 1 shows the number of cases, the results of treatment, complications and duration of treatment.

## SUMMARY

A method of closing a traumatic defect of a finger tip is described. This method more nearly restores the covering of the finger tip to a normal condition than any other procedure because palmar skin and subcutaneous tissue are used.

As in all plastic methods attention to detail is necessary, but the technic is not difficult.

The duration of treatment, much of which may be done in the out-patient department, is as short in the average case as most other methods of treating these injuries except amputation. About thirty to thirty-five days are necessary in the average case.

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## DISCUSSION

EDGAR L. GILCREEST (San Francisco, Calif.): Dr. Jones' paper is a very worth while contribution to the surgery of trauma even though it concerns itself with nothing more than the restoration of the tip of a finger. This, however, to a person who has lost it, is exceedingly important.

His method recommends itself because of its simplicity and further because it can be used so frequently. This accident occurs often in industry

but perhaps more often in the home. The flap of skin from the palm which Dr. Jones uses makes an ideal full thickness graft for the finger.

In 1926, I described in the Surgical Clinics of North America a restoration of the tip of a finger in which one-third had been lost by traumatic amputation. With rongeur forceps I bit off the bone until a flap of tissue on the palmar surface could be brought up, covering the bone. With a small, curved cutting needle threaded with silkworm-gut sutures, this flap of skin was brought up over the bone and the needle was passed through the remnant of the nail. Five sutures made a satisfactory approximation. I had never sewed a flap of skin to nail before and did not know that it would adhere below. I was delighted, therefore, at the end of a week, to see that this flap of skin had grown beneath the nail and after removal of the sutures there was no separation. I have not been able to find any case in the literature in which soft tissues had been sewed to the base of the nail. Six weeks after the operation she was able to play a piano, using the stump of the amputated finger just as well as the other fingers. The end of the finger, which at first had a blunt, fan-shaped appearance, rounded off like a normal finger. The length was exactly the same as her ring finger. The nail, of course, while only half-length, made an inconspicuous deformity.

I have seen several of Dr. Jones' patients on whom he had performed this operation and the results obtained were indeed splendid. I am inclined to believe that in most instances I would prefer his method to the one I used. His success is due to his careful and meticulous attention to every detail.

Carleton Mathewson, Jr. (San Francisco, Calif.): I feel unqualified to discuss this paper, because I have not had an opportunity to use the operation Dr. Jones describes. I have had the opportunity, however, of seeing one of Dr. Jones' patients, a typist who had an excellent functional and cosmetic result.

There are a few minor points which I think are important. Dr. Jones suggest the use of local block anesthesia in carrying out the operation. I might say that if you do use local anesthesia for blocking off the finger, you should avoid the use of adrenalin. We have seen gangrene of the tip of the finger which we attributed to interference in circulation caused by the use of adrenalin and novocaine. I think one cannot overemphasize the importance of thorough cleansing of the hand. We have found it very difficult to cleanse the hand thoroughly in any acute injury. Most of these injuries occur to people who, because of the type of their employment, have extremely greasy or dirty hands. I have watched nurses attempting to hold an extremity with one hand and clean it with the other. The results are not efficient, so that in the end one is dependent upon antiseptics rather than thorough cleansing for asepsis.

It has been my habit in these small injuries of the hand to block off the finger with local anesthesia, then to take the patient into the scrub room with me and show him how to scrub up for an operation, instructing him to scrub his hands at the same time. He rather enjoys it and you get the hand thoroughly cleansed.

Many patients think that we can perform miracles, which is often fortunate in this type of injury. Very often persons who have lost a portion of a finger or the whole finger, bring it in in a handkerchief. They usually pick up the abolated part, place it in a handkerchief, then run for the emergency hospital. If they do bring in the tip of the finger, very often you can cleanse it and suture it in place. Occasionally, it will take as a free graft and will give you a good functional result.

We have also found it useful in acute injuries that are still bloody to cleanse an area of skin on the forearm and then place the bloody tip of the finger on this area. In this manner one can outline accurately the size of a full thickness graft.

# THE TREATMENT OF FRACTURED PATELLA BY EXCISION*

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THE patella has been a bone of contention for a great many years. Because of its superficial location and the frequency of its fracture and refracture, it has always attracted considerable attention. In the treatment of fracture of this small bone, the great variety and number of methods in use throughout the nineteenth century give evidence of the unsatisfactory results commonly obtained. This was particularly true following conservative or nonoperative treatment, but also true to a lesser degree following open reduction.

It is the purpose of this presentation to endorse and advocate a newer and more satisfactory method of treatment and to present evidence of its success as applied in a relatively small recent series of cases.

## HISTORICAL

Up to 1870, fracture of this bone was with few exceptions treated conservatively by splinting the affected extremity in extension, by bedrest, elevation of the leg and massage. Convalescence was prolonged, bony union rare, and except for isolated instances the end results were far from satisfactory. Permanent disability in varying degrees was expected and more or less assured. In view of this fact and in an effort to get closer or bony union with resultant improved functional results, some of the more venturesome surgeons resorted to treatment by means of Malgaigne's hooks, Robson's and Anderson's pins, subcutaneous and pericutaneous suture and innumberable other methods which, though carrying greater risk and danger to the patient, showed little improvement in the end results.

## ARTHROTOMY WITH OSSEOUS SUTURE

In March, 1877, Sir Hector Cameron of Glasgow, Scotland, and in October of the same year, Lord Lister[1] treated patients with a fractured patella by opening the knee joint and wiring together the

* From the Fracture Service of the Edward J. Meyer Memorial Hospital, Buffalo, New York. Read before the annual session of the American Association for the Surgery of Trauma held at the Seignory Club, P.Q., May 30–31, 1941.

exposed fragments of the patella. This procedure, soon called "Lister's great experiment"[2] attracted the attention of the surgeons throughout the world.

Five years later, in 1883, Lord Lister presented seven cases to the London Clinical Society in which cure was obtained and staunchly advocated and argued for the procedure. For several years, however, this operation met with more or less universal scorn, ridicule and condemnation.

Objections and criticisms to it naturally centered around the risks and dangers associated with arthrotomy. In those early days of antiseptic surgery, suppuration, sepsis, ankylosis, amputation and death too frequently followed opening and exposing the largest synovial cavity in the body.

Dennis,[3] in 1885, in the course of investigating the history of wiring the patella was able to collect forty-nine cases performed previous to 1883 and from the literature and elsewhere collected 137 cases performed in the years 1883 to 1885. From this study and his own personal experience in the treatment of fractured patella by both open and closed methods, he concluded that the older methods were, in general, unsatisfactory. He agreed with Lister and likewise considered arthrotomy with metallic suture the ideal method of treatment at that time.

During the next few years this operation was performed with increasing frequency and ample evidence was soon accumulated to show beyond question of a doubt, that convalescence and restoration of function was more rapid and complete and that bony union was the rule rather than the exception following this new operation.

Stimson,[4] in 1898, citing his considerable personal experience,* stated, " . . . Resort to a method which involves risk to life or such disability as is produced by ankylosis or amputation, can be justified only when that risk is very small." He agreed that with open operation the period of convalescence and rehabilitation was much less and a good result more certain but added that when failures occurred, they were often disastrous. In his series of seventy consecutive cases 1892 to 1898 in which open incision was employed, close union and recovery without mishap occurred in all cases.

When one considers the remarks of Dennis as well as Bull[5] relative to the usual convalescence and end result following the older

* His experience comprised subcutaneous mediate silk suture through the tendon and ligamentum patellae, about forty cases 1889 to 1892 and open incision with the same or fibroperiosteal suture, about seventy cases 1892 to 1898.

methods of treatment of fractured patella, he can appreciate how and why the newer method, once established, was received with universal acclaim. Dennis in a long list of objections to the older methods of treatment mentioned, " . . . partial and complete ankylosis, pain in the joint, the necessity for crutches often for two years, the wearing of a knee cap, the use of a posterior splint for life, the strong probability of refracture, the sense of insecurity in standing, the constant fear of falling, the inability to walk with any certainty, the muscular atrophy of the limb, the tedious and long convalescence and many other conditions too numerous to mention and too familiar to all."

By 1900, the open operation had become quite popular, for with the development of antiseptic and later aseptic surgery, the chief obstacle—infection—was rapidly overcome. Many of the prominent surgeons of this country and abroad were using this method and advocating its general adoption. Powers,[6] in 1898, collected and cited the experience of some seventy-one American surgeons who treated 679 patients with fractured patellas by open arthrotomy with no amputations and only three deaths. Satisfactory results were reported in 94 per cent of these cases. He concluded from his investigation, that this procedure had at that time a well fixed place in surgery and had received the endorsement of the majority of the prominent American surgeons.

Heineck,[7] in 1909, analyzed 1,100 cases of fractured patella treated by the open operative method during the previous ten years and concluded from the available statistics that the risk from open arthrotomy in skillful and careful hands was practically nil. He, too, considered the open operation as the method of choice.

Three types of operation were at that time most popular. All included arthrotomy as the first step; all included careful repair of the soft parts as an essential step. They were: (1) osseous suture, (2) cerclage, (3) "suture des ailerons."* Excellent functional and anatomical results were obtained with each of these methods and it is interesting to observe that most of the advocates of osseous suture emphasized early the importance of repairing the lateral and medial tendinous expansions of the quadriceps tendon.

Since 1910, open reduction has been generally accepted and taught as the operation of choice in the treatment of transverse frac-

* Peyrot said, "In fractured patellae, absolutely perfect results from the standpoint of contour, solidity and function have been obtained in a relatively short period in cases in which all suturing was limited to praepatellar and parapatellar tissues."

ture of the patella with separation of fragments. Many and varied ways of holding the fragments together have been described and used, some quite ingenious, all claiming some merit. All types of suture material have been used including wire of all kinds, gut, tendon, fascia, linen, silk, etc. Nails, screws, Lane plates and even inlay grafts also have their advocates who at times have claimed much for their particular choice; but regardless of the method advocated or used, all strove to secure bony union with relatively prompt and complete recovery of function.

That bony union occurred more frequently following open operation, there can be no doubt, but that there were numerous failures to obtain such union is equally unquestionable. Results were obviously better but some of the objections and complications attributed to the older methods of treatment evidently continued to exist with the new.

In 1910, Corner,[8] of London, published some interesting figures about fracture and refracture of the patella as seen at St. Thomas' Hospital. His statistics relate to those cases admitted between 1890 to 1907 inclusive, some 504 in number. Some of these statistics seem relevant for which reason a few are listed. Transverse fractures were the most frequent, comprising 85 per cent, comminuted fractures were next most frequent, comprising 10 per cent. Compound fractures were seen in only 1 per cent of cases. Two patients underwent operation for every one which did not. The patella was sutured in 65 per cent of cases. Splints and massage were used in 35 per cent of cases. The patella was the most frequently refractured bone in the body.

The percentage of refractures was approximately the same after either operative or nonoperative treatment,* 10 per cent in the case of suture of the fragments, 9 per cent after other treatment. The information furnished by these statistics of Corner is significant even though disappointing, for one of the chief advantages claimed for the open operation seems to have been established not so well as was thought. If other and later reports show similar figures relative to refracture, one would be obliged to assume that the advantages of open suture of the fragments are solely in the relatively complete and quick recovery of function in the limb.

* It was observed that after suture 69 per cent of refractures occurred within the first year and 88 per cent within the first three years. In patients receiving treatment, other than suture, 14 per cent of refractures occurred within the first year and 86 per cent after the first year.

The wave of enthusiasm for open reduction during the years 1885 to 1910, though slow in getting started, had by this time (1910) swept all obstacles and criticism aside and the operation now received general commendation. The advantages claimed seemed to have been substantiated by experience: (1) Great risk to life and limb had been eliminated. (2) The fact that bony union could be obtained was established. (3) Repair was more rapid with the open operation. (4) Results were superior as regards function of limb and knee joint.

Arthrotomy with safety, bony union, rapid repair and good function sum up in a few words the contribution of Lord Lister and his followers to the treatment of patellar fractures.

### END RESULTS FOLLOWING OSSEOUS SUTURE

Powers, nevertheless, in his very thorough investigation as to the question of operative interference, was not completely satisfied with the results reported and very aptly expresses what we believe is still true today, " . . . But in the matter of ultimate results our conclusions must be in large part inferential, as with but few exceptions the cases have been reported too soon after operation. They are instances of operative recovery, and they permit an expression of the individual opinions of the reporters, but they unfortunately do not warrant judgment as to the definite usefulness of the limb after the lapse of a suitable length of time . . . The cases should be thoroughly tested after a lapse of one or two years, for in no class of fractures does time make greater changes . . . Tests should be made systematically and should be both structural and functional . . . The truest test as to result is the ability to walk long distances, to pursue arduous occupations, to easily ascend and descend stairs and the like . . . But very few of the reported cases bear this examination."

We have in our limited experience seen quite a few patients of others as well as our own, who, after a period of from one to fifteen years following open reduction for fractured patella, still have considerable loss in knee joint function (usually limitation in flexion) although the limb must be considered a very useful one. We must also admit that after investigation and from our own observations, the usual postoperative treatment and convalescence following open reduction still occupies a considerable period of time, comprising in many instances four to six weeks' hospitalization and as many months before the patient is able to return to any arduous work. This relatively prolonged period of disability is no doubt the result

of overconservatism displayed in an effort to prevent refracture and it is quite probable that splinting and immobilization has in the past been unnecessarily prolonged.

### EXCISION OF THE PATELLA PARTIAL AND COMPLETE

Notwithstanding the markedly improved results which followed the treatment of fractured patella by open reduction and osseous suture, much was left to be desired and there is still considerable room for improvement. It is not surprising therefore that partial and complete excision rather than repair of the fractured patella was next considered, suggested and performed.

Chaput,[9] in the description of his several methods of treating fractured patella in 1891, discussed the treatment of old fractures and called attention to a type wherein the superior fragment impaired flexion. In this type he performed with good result and recommended extirpation of the offending superior fragment. In another type* in which the patella was too long and interfered with flexion because of its excessive length and breadth, he advised complete extirpation and stated that the operation was easy and was not followed by any functional disturbance.

Stimson, in 1898, discussing the treatment of old fractures of the patella resulting in diminution of function stated, "It is known that partial or total loss of the patella does not involve loss of function; the quadriceps retains control of the leg through its fibrous and fascial connections . . . "

Heineck, in the analysis previously referred to, comprising 1,100 cases, was able to find in the literature thirteen cases in which the removal of the patella constituted the sole operative procedure on the knee joint. Of these, five were for fractures, four for tuberculosis, three for chronic osteomyelitis and one for malignancy. From the study of these as well as cases of congenital absence, he concluded that a deficiency or absence of the patella was invariably associated with an impairment in function and power. His strong and definite feeling in this matter is quoted, "In uncomplicated transverse fractures of the knee cap, the extirpation of the patella as a form of treatment is to be condemned. In comminuted fractures it deserves consideration only as a measure of last resort."

It would seem that the few cases at that time available for study scarcely justified the attitude assumed and so strongly expressed,

* "Old fractures of the patella with a rigid callus with elongated patella and impaired flexion should be treated by complete extirpation of the patella." (Chaput.)

relative to the indispensability of the patella and the functional impairment resulting from its loss. It would seem more than likely that the impairment in function was the result of associated damage, disease or neglect to the soft parts and not to the absence of the patella. His dogmatic statement to the effect that a knee joint without a patella is an impaired joint, seems to have been made upon inadequate evidence, notwithstanding the fact that included in the cases he was able to collect and publish from the literature, were three belonging to Mr. W. Morey Willis[10] who on December 4, 1907, reported before the Nottingham Medico-Chirurgical Society these three cases in which he had completely excised the patella for fracture. At that time he demonstrated his last case which had been operated upon five months previously. The movements of the joint were perfect and he reported that the results in the other two cases were also excellent. In all three cases he regarded the result as equal if not superior to that obtained by wire suture. In this same collection of cases by Heineck was also included a case of Dr. Charles L. Scudder.[11] This patient suffered marked comminution of both patellae and after complete excision of both, was reported to have excellent functional use of both knees. There are, undoubtedly, many other cases either unreported or not found in the earlier literature which, like the cases of Willis and Scudder, would lend additional evidence tending to invalidate the deductions of Heineck.

Thomsen,[12] in 1934, recommended partial excision of the patella in cases of fresh fracture showing comminution in which there were one large fragment and several small fragments. He believed that by excising the several smaller fragments, only union of tendinous structures was involved and success assured. He reported that the results obtained in his five cases were uniformly satisfactory.

Blodgett and Fairchild,[13] of the Receiving Hospital in Detroit, Michigan, reported their experience with partial and total excision of the patella for acute fracture. At that institution during the years 1932 to 1934 inclusive, fifty-five cases required open reduction, thirty-five of these patients were treated by various suturing processes and twenty were treated by partial or total excision of the patellar fragments. The end results in both groups are interesting in that few such statistics have been published. From them one ascertains that the end results following osseous suture were far from satisfactory and partial or complete excision of the patella has some merit. The reported end results follow:

"Of the 35 cases repaired by various suturing processes, in twenty the results were unknown. Only fifteen cases could be examined and appraised from seven to thirty-six months postoperative. Of these:

| | |
|---|---|
| 7 classified excellent... | Limb and knee joint useful as before |
| 3 classified good..... | Improving, nearly full flexion, moderate difficulty in getting up and down stairs. |
| 5 classified fair..... | Fair economic usefulness, function often considerably diminished. |

"Of the twelve cases treated by partial excision, in five the results were unknown. Only seven could be examined from six to twenty-six months postoperative. Of these, six were rated as excellent and one good.

"Of the eight cases treated by complete excision, in four the results were unknown, one was rated as excellent and three were rated good."

It is worthy of note that in the above series of cases the results following osseous suture were far from satisfactory, less than 50 per cent of the followed cases showing a limb or knee joint as useful as before the accident. It is unfortunate that end results were obtainable in only 50 per cent of the excision cases. From this small group of cases (eleven cases) and as particularly shown in the complete excision group, the superior end results following excision were not convincingly demonstrated. The authors (Blodgett and Fairchild) were never the less convinced that partial and total excisions of the patella were productive of excellent results. They believed that many disadvantages encountered in osseous repair such as, inaccurate reposition of the posterior articular surfaces of the fragments, subsequent adhesions to the femur and in some cases the necessity of removing wire suture material were eliminated by excision. They also observed that convalescence and rehabilitation were considerably shortened. If there was a sizable lower fragment, they recommended excision of the upper fragment or fragments. In cases of marked comminution with wide separation and in those in which there was no sizable lower fragment they recommended total resection.

In April, 1937, R. Brooke,[14] of England, reported thirty cases in which the patella had been completely excised during the seven years previous to publication. From his personal experience he was impressed " . . . with the rapid and smooth recovery and the relatively very complete recovery of function permitting laboring men to

return to their work within a month or six weeks of the operation." His presentation though startling, was convincing. His conclusion, short and precise follows, "The patella is an integral part of the skeleton phylogenically inherited, and function plays no part either in its formation or its growth. In man it subserves no important function. It is a morphological remnant which is tending to undergo reduction and to disappear. It has become modified to take part in movements of the knee joint, but its presence is incidental and is a deterrent rather than an aid to these movements. Experimental and other evidence has been advanced to show in its absence the efficiency of the knee joint is, if anything, increased both as regards the rapidity of movement and power." Such a statement is to the average person difficult to believe and quite provocative.

Groves,[15] of Bristol, editor of the *British Journal of Surgery*, admitted that he, too, was quite skeptical when he heard of Mr. Brooke's claims and requested to see some of the results. Mr. Brooke showed him eight cases after which Groves admitted that the claims were fully justified stating, that when the knees were covered it was impossible in any case to identify the injured limb or detect any difference in function. "Convinced but still mystified as to how the mechanism of the extension of the knee could be so perfectly carried out in the absence of the patella, I sought the help of Professor Whitnall of Bristol University, Anatomical Department." Together, after studying anatomical preparations they were convinced that it was the suture of the lateral tendinous expansions of the quadriceps tendon which was most important and concluded that by removing the fragments a better repair could be obtained.

Since the report of Brooke, Tippett[16] reported in 1938 the results in four excision cases, Mehriz,[17] in 1939, the result of a single case and Dodd,[18] in 1939, enthusiastically endorsed the procedure reporting excellent results in five cases.

## THE PRESENT SERIES OF CASES

The article by Brooke, of England, previously referred to, brought to our attention this new and startling method of treating fractures of the patella. The advantages claimed were so convincingly demonstrated in photographs that we decided to give the procedure a trial.

We have since November, 1937, on the Fracture Service at the E. J. Meyer Memorial Hospital, treated all patients with a fractured patella with comminution and separation of fragments by complete

excision. In other words, any case requiring open operation was treated by complete excision of the fragments.

Our experience during the past three and one-half years comprises twenty-one cases. Twelve service patients and one private patient were operated upon by the authors. Eight private patients were operated upon by five other local surgeons. With one exception the results obtained have been most satisfactory and gratifying. Table I shows the distribution of cases over forty-one consecutive months. It is interesting to observe that the first private patient was treated by excision only after impressive experience and end results had been observed in five service patients operated upon during the preceding twenty-two months. In summary, Table II supplies the following data:

*Age Incidence.* The oldest patient was a woman of seventy-nine years, the youngest a boy of eighteen years. The average age for the entire group was fifty-two years.

TABLE I

ANALYSIS TWENTY-ONE EXCISION CASES ACCORDING TO CASE STATUS AND DISTRIBUTION OVER YEARS

| Nov. 1937 to Mar. 1941 | Service Cases | Private Cases | Total Cases |
|---|---|---|---|
| 1937 | 2 | 0 | 2 |
| 1938 | 2 | 0 | 2 |
| 1939 | 1 | 1 | 2 |
| 1940 | 5 | 6 | 11 |
| 1941 | 2 | 2 | 4 |
| Total | 12 | 9 | 21 |

*Sex.* There were fourteen males and seven females; ratio 2:1.

*Right and Left Patella.* The right patella was fractured in eleven cases, the left in ten cases. In only one instance were both patellae fractured, only the left requiring operation because of marked comminution and wide separation of fragments (Case 11).

*Complicating Factors.* The fractures were simple in all but one instance (Case 6) which was compounded. Two of the cases (3 and 13) were refractures, in each instance the same patella having been fractured and sutured on two previous occasions. Two cases (11 and 17) had associated injuries which either delayed convalescence or complicated the end result. The patient in Case 11 sustained fractures of both right and left patellae. The right, though comminuted,

TABLE II

PATELLAS EXCISED FOR FRACTURE

(Twenty-one cases in forty-one months)

| Case No. | Private or Service | Case Initials | Sex | Age | Patella | Date Injured | Date Operated | Interval between Injury and Operation | Injuries Complicating | Hosp. Days P.O. | Time since Oper. | End Result |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Service | P. F. | M | 53 | left | 11/6/37 | 11/6/37 | 24 hours | none | 40 | 41 mo. | Excellent |
| 2. | Service | J. Y. | M | 71 | right | 11/30/37 | 12/14/37 | 14 days | none | 41 | 40 mo. | Excellent |
| 3. | Service | W. B. | M | 62 | left | 3/25/38 | 3/30/38 | 5 days | 3rd. time fractured | 18 | 36 mo. | Excellent |
| 4. | Service | M. G. | M | 18 | left | 5/25/38 | 5/26/38 | 24 hours | none | 21 | 34 mo. | Excellent |
| 5. | Service | H. A. | M | 41 | right | 5/6/39 | 5/6/39 | 24 hours | none | 27 | 22 mo. | Excellent |
| 6. | Private[20] | E. J. | M | 27 | right | 8/31/39 | 8/31/39 | 24 hours | fractured humerus | 18 | 19 mo. | Excellent |
| 7. | Private[21] | C. C. | M | 54 | right | 12/22/39 | 1/8/40 | 17 days | none | 16 | 14 mo. | Excellent |
| 8. | Service | E. N. | M | 41 | left | 2/15/40 | 2/17/40 | 2 days | none | 21 | 13 mo. | Excellent |
| 9. | Service | S. G. | M | 57 | left | 3/23/40 | 3/25/40 | 2 days | none | 21 | 12 mo. | Excellent |
| 10. | Private[22] | P. A. | M | 60 | left | 6/8/40 | 6/11/40 | 3 days | none | 21 | 9 mo. | Excellent |
| 11. | Private | E. S. | M | 33 | left | 7/5/40 | 7/9/40 | 4 days | fracture both patellae | 42 | 7th week | Died |
| 12. | Private[21] | M. J. | F | 50 | left | 10/7/40 | 10/15/40 | 8 days | none | 21 | 5 mo. | Excellent |
| 13. | Private[23] | F. S. | F | 53 | left | 11/1/40 | 11/8/40 | 7 days | 3rd. time fractured | 16 | 4 mo. | Excellent |
| 14. | Private[24] | J. L. | F | 53 | right | 11/4/40 | 11/12/40 | 8 days | none | 27 | 4 mo. | Excellent |
| 15. | Service | L. P. | F | 42 | right | 11/21/40 | 11/23/40 | 2 days | none | 21 | 4 mo. | Excellent |
| 16. | Service | J. B. | M | 51 | left | 11/15/40 | 11/26/40 | 11 days | none | 21 | 4 mo. | ? |
| 17. | Service | I. P. | F | 54 | right | 11/30/40 | 12/4/40 | 4 days | fracture opposite ankle | 42 | 3 mo. | ? |
| 18. | Service | H. S. | F | 79 | right | 1/8/41 | 1/16/41 | 8 days | none | 40 | 2 mo. | Excellent |
| 19. | Private[23] | G. B. | M | 55 | right | 1/20/41 | 1/24/41 | 4 days | none | 9 | 2 mo. | Excellent |
| 20. | Private[20] | J. W. | F | 72 | right | 2/2/41 | 2/2/41 | 24 hours | none | 12 | 2 mo. | ? |
| 21. | Service | P. N. | M | 58 | right | 11/29/40 | 3/17/41 | 107 days | none | 21 | 1 mo. | ? |

showed no displacement of fragments and was treated by splinting only, whereas the left because of marked comminution and separation of fragments, was treated by excision. Because of disability in both legs, he was confined to bed for five weeks. After walking for two weeks and having been home one week, he was able to walk one-quarter mile and negotiate stairs with the aid of a cane. He died suddenly on his forty-seventh postoperative day. Autopsy showed massive pulmonary embolism. The period of hospitalization was in this case unusually prolonged, the end result extremely poor. The patient in Case 17, in addition to the fractured patella, sustained a trimalleolar fracture of the opposite ankle treated by reduction and plaster cast. She was an extremely heavy woman and because of her injuries and weight was confined to bed for five weeks. In this case also hospitalization was prolonged to six weeks.

*Period of Hospitalization.* Excluding Cases 11 and 17 for reasons mentioned, the period of postoperative hospitalization is analyzed in nineteen cases according to their status as service or private cases. (Table III.)

The average postoperative period of hospitalization for the entire group of uncomplicated cases was 22.7 days. The substantial difference in the length of postoperative hospitalization, shown to be nine days longer in the service than in the private cases is accounted for in a number of ways. The patients in Cases 1 and 2, the first cases, were rehabilitated slowly and cautiously and being indigent patients to

TABLE III
HOSPITALIZATION. POSTOPERATIVE DAYS
(Nineteen cases)

| Case Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | Total Days | Average Days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Service case days | 40 | 41 | 18 | 21 | 27 | .. | .. | 21 | 21 | .. | .. | .. | .. | 21 | 21 | 40 | .. | .. | 21 | 292 | 26.5 |
| Private case days | .. | .. | .. | .. | .. | 18 | 16 | .. | .. | 21 | 21 | 16 | 27 | .. | .. | .. | 9 | 12 | .. | 140 | 17.5 |
| All cases | (Nineteen cases, service and private) | | | | | | | | | | | | | | | | | | | 432 | 22.7 |

whom time meant nothing, they were quite satisfied to remain in the hospital forty and forty-one days, respectively, for purposes of observation. Both could have been discharged several weeks earlier. Case 18, a feeble old lady, having no one to care for her at home, was thought to be better off in the hospital until she could care for herself and for this reason remained in the hospital forty days.

From our small and limited experience the patients without complications are, with rare exceptions, walking well without dressings, aid or discomfort at the end of the second week; and as no physiotherapy other than active use is prescribed, there is no reason for keeping them in the hospital for any appreciably longer period of time. As shown in Table III, the average postoperative period of hospitalization for the eight private cases was two and one-half weeks.

*Interval between Injury and Operation.* The time elapsed between fracture and excision varied considerably. (Table IV.) In general, each patient was operated upon as soon after admission as seemed practical. The preoperative condition and preparation of the patient as well as reasonable convenience, were all taken into consideration. It is our impression that delay offers no advantages. Provided that there are no gross contraindications to immediate arthrotomy or any valid reasons for delay, immediate operation is advised.

Our experience in this series, excluding the most recent patient (Case 21) who first consulted a physician three and one-half months after injury, shows that the average time interval between injury and operation amounted to 5.5 days.

5 patients or 24 per cent were operated upon within twenty-four hours or less.

8 patients or 38 per cent were operated upon within forty-eight hours.

12 patients or 57 per cent were operated upon within four days.

9 or 75 per cent of the service patients were operated upon within five days of injury.

TABLE IV

TIME ELAPSED BETWEEN INJURY AND OPERATION

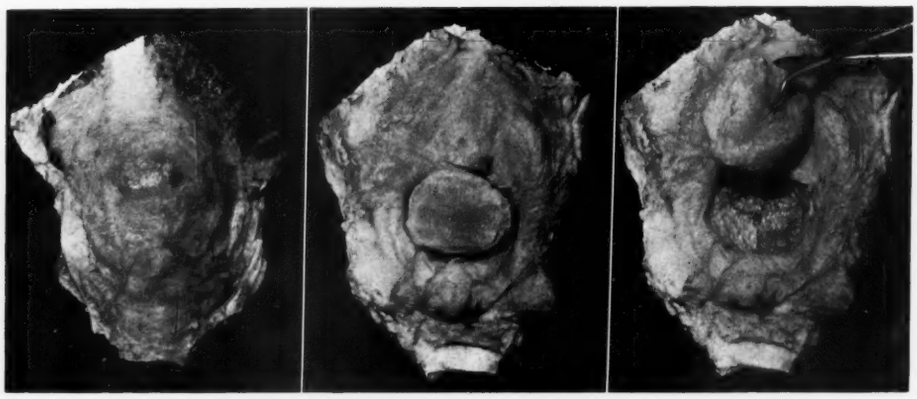
(Twenty-one cases)

| Interval between injury and Operation | Case Numbers | |
|---|---|---|
| 24 hours or less | 1, 4, 5, 6, 20 | —24% operated upon 24 hours or less |
| 2 days | 8, 9, 15 | —38% operated upon within 48 hours |
| 3 days | 10 | |
| 4 days | 11, 17, 19 | —57% operated upon within 4 days |
| 5 days | 3 | |
| 7 days | 13 | |
| 8 days | 12, 14, 18 | |
| 11 days | 16 | |
| 14 days | 2 | |
| 17 days | 7 | |
| | ——— | —20 cases. Average 5.5 day interval between injury and operation. |
| 107 days | 21 | |

The average time interval would have been considerably less had all of the cases entered the hospital immediately after injury.

## ANATOMICAL CONSIDERATION

It should be recalled that the quadriceps femoris muscle, powerful extensor of the leg, consists of four different heads viz., the rectus



A B C

FIG. 1. Fresh cadaver specimen showing normal relation of patella to quadriceps tendon. A, viewed from the front showing quadriceps tendon, the lateral and medial tendinous expansions, the patella and patellar ligament. B, same as (A) viewed from behind, showing articular surfaces of the same structures. Observe that the posterior surface of the tendon is attached to the anterior surface of the patella. C, same as (B) showing the patella detached from the posterior surface of the tendon and reflected proximally. Note the relatively small patellar defect in the tendon and the strong tendinous lateral and medial expansions.

femoris, vastus medialis, vastus lateralis and vastus intermedius, all of which converge and unite to form the quadriceps tendon. This broad, common tendon of insertion passes over the patella to become continuous with the patella ligament which is inserted into the tuberosity of the tibia. The quadriceps tendon, in addition to being firmly attached to the anterior surface and lateral margins of the patella, furnishes tendinous lateral and medial expansions which pass downward to be inserted into the margins of the lateral and medial condyles of the tibia, respectively. The superior and inferior articular margins of the patella are covered with fat and there are no ligamentous fibers attached thereto.

Because of its relation and attachment to the quadriceps tendon, the patella can be readily dissected free from the posterior surface of the tendon. This is well demonstrated in Figures 1A, B, C and D which are photographs of a specimen taken from a fresh cadaver. From them, one can readily understand why removal of the patella

FIG. 1D. Longitudinal section of the same specimen, showing tendon from which the normal patella has been excised. (See Fig. 19C).

does not interfere with subsequent function, there being no appreciable loss in tendon continuity provided the lateral and medial tendinous expansions are well repaired.

### THE OPERATION

*Indications.* Any simple fracture of the patella with separation of fragments which requires open operation and all compound fractures require operation.

*Preoperative Preparation.* From the time of injury to operation, the injured extremity is elevated and splinted comfortably in extension. In view of the fact that early operation is contemplated and usually performed, little or no benefit is to be expected from pressure bandages, hot or cold applications, etc., and they are therefore not used. Careful preoperative examination and study of the patient is of course carried out the same for this as any other operation. Preoperative treatment and sedation naturally varies with the surgeon and the type of anesthesia to be used. Low spinal anesthesia was found to be very satisfactory and was used in most, though not all of the cases of this series.

The field of operation is prepared according to the custom and desire of the operating surgeon. The authors scrub the entire extremity from groin to ankle thoroughly with ether. Tincture of iodine is then applied over the same area and after it has dried it is removed with alcohol. The operative field is then draped so as to expose the knee generously.

*Incision.* Either a transverse or vertical incision, six to eight inches long, centered over the patellar fragments will give adequate exposure permitting excision of the fragments and repair by suture of the tendon and tendinous expansions. (Fig. 2A.)

The incision divides skin and fascia immediately exposing the line of fracture and the contused, lacerated soft tissues. Considerable and varying amounts of blood, bloodclot and synovial fluid escape from the knee joint. Retraction of the wound edges reveals the extent of the lacerations of the lateral and medial tendinous expansions, which is usually extensive. (Fig. 2B.)

*Excision of Patellar Fragments.* The number of fragments depends upon the extent of comminution. Commonly, there are one large proximal and several smaller distal fragments. The rents in the lateral and medial tendinous expansions of the quadriceps tendon make it possible to evert or turn out these fragments. This step is facilitated by the use of a towel clip, which permits firm traction and

eversion of the fragment away from the fracture line. (Fig. 2C.) By sharp dissection and at the same time closely hugging the anterior surfaces of the patellar fragments, they are removed with special care to preserve intact the overlying tendon.

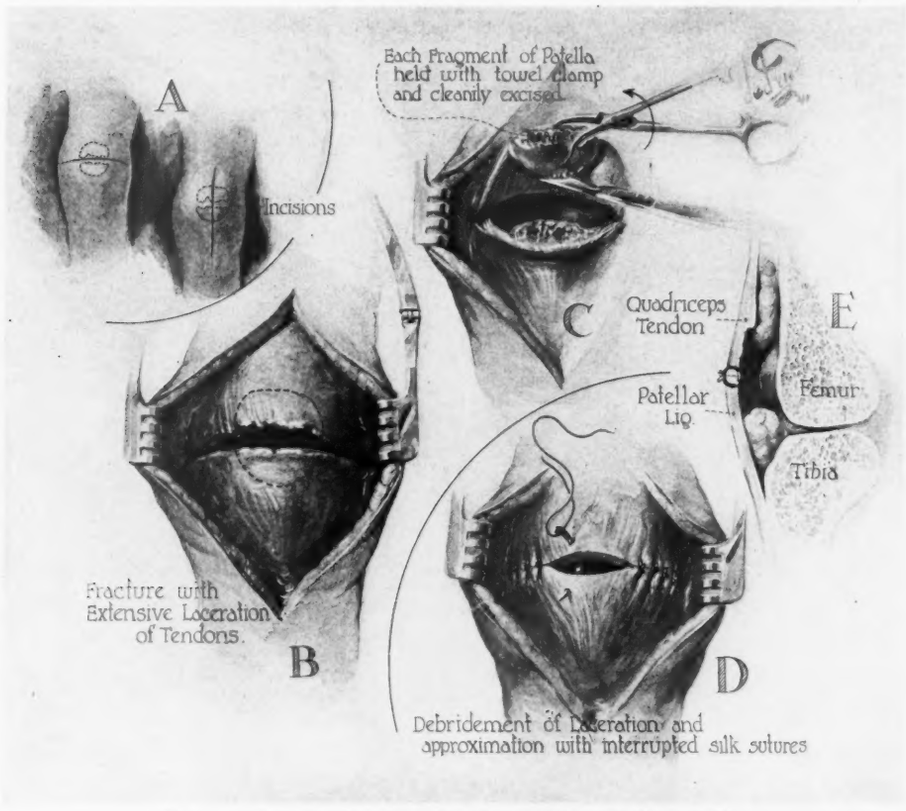



FIG. 2. Steps in the operation for excision of the patella.

*Repair of Tendon and Lateral Tendinous Expansions.* After the fragments have been completely excised, the contused and hemorrhagic, frayed, adjacent edges of the tendon and tendinous expansions are sparingly débrided and repair is completed by approximating the freshened edges with interrupted sutures. Any hemorrhage encountered should be accurately controlled by ligature and special care is exercised to see that the tendinous expansions are sutured well laterally and medially without tension. It is advantageous to suture the lateral and medial tendinous expansions first for by so doing, the much thinner, central portion of the tendon, originally attached to the patella, is approximated with greater ease and less tension. (Fig. 2D.)

*Closure of Wound.* The wound is closed in two layers, fascia and skin, by interrupted, continuous or subcutaneous suture depending upon the type of suture material used. A sterile, snug pressure bandage is applied. No splinting of any type is necessary or used.

*Suture Material.* In this series of twenty-one cases, various kinds of suture material were used, there being a marked preference shown for silk.

| | | |
|---|---|---|
| No. 10 black silk | was used in | 10 cases (5, 6, 8, 9, 11, 15, 17, 18, 20, 21) |
| Chromic catgut | was used in | 6 cases (1, 4, 7, 10, 12, 14) |
| Fascia lata | was used in | 2 cases (2 and 3) |
| Alloy wire | was used in | 2 cases (13 and 19) |
| Chromic and silk | were used in | 1 case (16) |

Of the thirteen patients operated upon by the authors, silk was used in eight, fascia lata in two, chromic gut in two and silk and chromic gut in one. From the observation of the convalescence in this small group of cases, it would appear that the type of suture material used was immaterial. It seems logical, therefore, to recommend that suture material least apt to cause tissue reaction be used.

## POSTOPERATIVE CARE AND REHABILITATION

The operative wound having been closed and dressed, several layers of sheet wadding are applied over the sterile protective dressing and the entire knee is snugly bandaged with a five-yard flannel bandage.

The patient is at once permitted and encouraged to move freely about in bed and there is relatively little discomfort which is controlled with mild sedatives.

On the third or fourth day, he is allowed out of bed and encouraged to walk about, with or without the aid of a cane, according to the desires of the patient. This step is, as a rule readily accomplished with great surprise and satisfaction to the patient. Upon realizing that he is able to walk with little or no discomfort and only a slight limp, he is more than willing to follow enthusiastically the active exercises outlined and prescribed. Progress is amazingly rapid from this stage. During the first week, the snug flannel bandage is left undisturbed. In addition to compressing and protecting the operative site, any marked degree of flexion is prevented and the sense of support and security afforded by its presence inspires confidence.

Between the seventh and tenth days, the wound is dressed for the first time. The stitches are removed, all dressings discarded and active flexion and extension exercises are instituted. By the end of

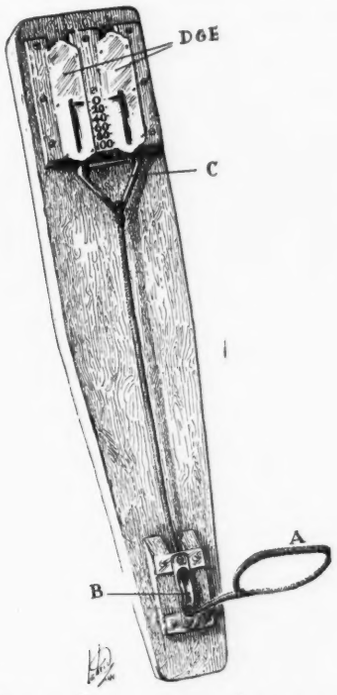



FIG. 3. Dynamometer for measuring quadriceps extensor femoris muscle power. The patient places the heel of the shoe on the limb to be tested in cable loop (A). The attached cable extends around pulley (B) and passes upward to arm (C) connecting two parallel fifty-pound spring scales (D and E) which are firmly mounted on a stout board. The instrument is held between the legs of the patient. In a sitting position, both buttocks placed squarely and well back on a suitable chair or table top, quadriceps extension power is recorded in pounds 0 to 100. See photographs of dynamometer in use. (Figs. 4D, 5D and 8D.)

the second week complete extension and 90 degrees flexion have usually been obtained and the patient gets around actively and comfortably without aid of any sort. It is quite impressive to see these patients at this stage, walking about the wards and hospital corridors as well or better than many of their fellow convalescent patients who had no injury or operation.

The patient is discharged from the hospital at this time with instructions relative to the active use of the operated extremity. He is encouraged to do a considerable, increasing amount of walking daily and is instructed to walk up and down stairs whenever and as much as possible. To negotiate stairs is the most difficult part of rehabilitation and this important criterion of function is the last obtained.

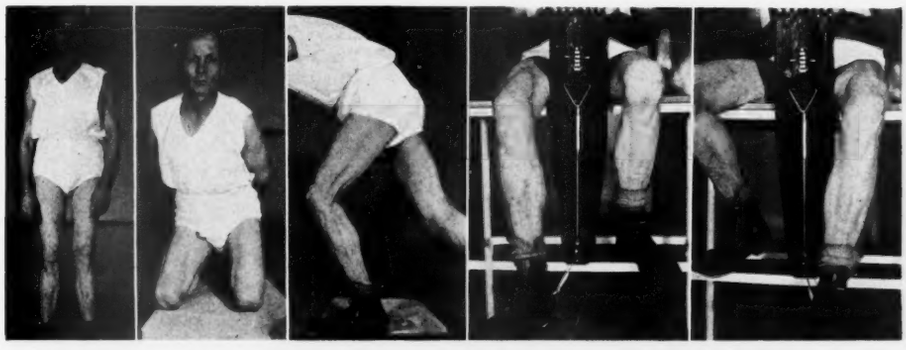
With progressively increasing active use, the patient is, at the end of six to eight weeks able to be on his feet all day, walk long distances and negotiate stairs. In many instances he is able to return to laborious work including climbing between the second and third month.

Full and complete function is demonstrable in some earlier than in others depending upon the amount of stoicism and co-operation displayed. Compensation and lawsuits will exert their influence unfavorably of course, but generally speaking from the end results obtained in this series there is no functional impairment at the end of four months.

## END RESULTS

The end results in this series of cases were critically evaluated by more than one observer and because of the unbelievable excellent result almost invariably obtained, many of the cases have been shown to the sceptics on numerous occasions. The result as here recorded was considered excellent only when the function of the limb and knee joint was observed to be normal in all respects. Such classification required: (1) Powerful and complete extension of the injured leg equal to that of the uninjured extremity; (2) complete flexion of the leg on the thigh, equal to that of the uninjured extremity; (3) the ability to kneel and rise from kneeling position without discomfort; (4) the ability to bear the body weight on the semiflexed injured extremity alone; (5) the ability to walk long distances comfortably, normally and without a limp; (6) the ability to negotiate stairs normally and comfortably; (7) the feeling of stability and security in the injured extremity; (8) complete lack of subjective complaints

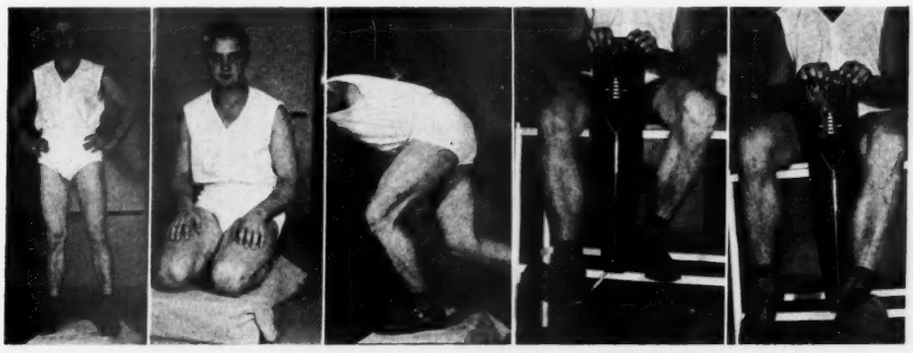
suggesting disability or inferiority as compared to the uninjured extremity; and (9) in those cases in which pre-existing disability made it impossible to fulfill the preceding requirements, the result



A B C D E

FIG. 4. Case I. Laboror, age fifty-three, photographed thirty-six months postoperatively. Left patella excised November 6, 1937. A, full function six weeks. It is difficult to identify the affected knee. B, kneeling and full flexion demonstrated. C, body weight easily supported on semiflexed affected limb. D, extension power unaffected limb forty-two pounds. E, extension power affected limb fifty pounds.

was considered excellent when the function obtained was said to be equal or better to that present immediately prior to the patella injury. (Cases 3 and 13.)



A B C D E

FIG. 5. Case IV. Laboror, age eighteen, photographed thirty months postoperatively. Left patella excised May 26, 1938. A, full function three months. It is difficult to identify the affected knee. B, kneeling and full flexion demonstrated. C, body weight easily supported on semiflexed affected limb. D, extension power unaffected limb sixty pounds. E, extension power affected limb sixty-four pounds.

Such an evaluation as described is indeed critical and demanding but, nevertheless, essential to substantiate the extravagant claims of those advocating the procedure of excision of the patella for fracture. Very few cases of fractured patella, regardless of the method by

which they were treated, have been analyzed so critically as far as end results are concerned.

Of the twenty-one cases in this series, one (Case 11) patient died

A B C D

FIG. 6. Case v. Dining car waiter, age forty-one, photographed eighteen months postoperatively. Right patella excised May 6, 1939. Full function six weeks. A, it is difficult to identify the affected knee. B, kneeling and full flexion demonstrated. C, squatting and full flexion. D, body weight easily supported on semiflexed affected limb.

in the seventh postoperative week, the result of pulmonary embolism. Progress up to the time of death promised an excellent result.

Of the twenty patients surviving the operation, in two instances (Cases 20 and 21) not sufficient time had elapsed when last examined to expect or warrant the recording of complete return of function.

Two of the remaining eighteen patients (Cases 16 and 17) failed to respond or report for end result check up in time for this report, though our latest out-patient follow-up records showed them to be progressing satisfactorily.

In sixteen cases we were able to demonstrate an excellent result from three to forty-one months postoperatively without exception or exaggeration. All of them have returned to their usual work as laborers or housewives.

Photographs of the end results in several of the cases of this series are submitted to demonstrate the completeness of functional return. (Figs. 4, 5, 6, 7, 8, 9 and 10.)

### DYNAMOMETER TEST FOR QUADRICEPS POWER

A dynamometer for measuring the power of the quadriceps femoris muscle was improvised by the senior author. It is quite simple in construction and operation. (Fig. 3.) For purposes of

comparison and progress determination, it has proved quite valuable as a means to portray visually and record the power of extension in pounds.

A B C

FIG. 7. Case VIII. Laboror, age forty-two, photographed nine months postoperatively. Left patella excised February 17, 1940. A, it is difficult to identify the affected knee. B, kneeling and full flexion demonstrated. C, body weight easily supported on semiflexed affected knee.

In those cases tested it has been constantly observed that the power of extension is unimpaired following the complete removal of the patella and strange as it may seem, in many of the cases power is from three to eight pounds greater in the limb from which the patella has been excised than in the unaffected extremity.

## REGENERATION OF THE PATELLA

Blodgett and Fairchild stated, "The patella does not regenerate following excision." This statement of fact seems to have been based on a single case which showed no radiographic evidence of regeneration six months after excision.

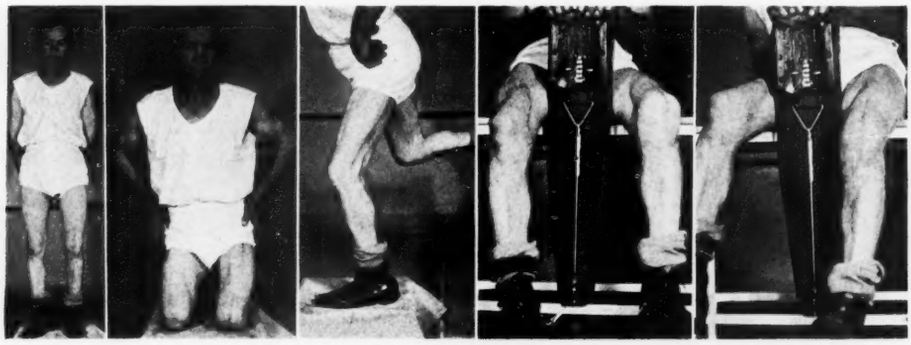
Brooke, in reciting his larger experience, did not touch on the subject of regeneration.

Carey,[19] Zeit and McGrath, however, in their studies in the dynamics of histogenesis with particular reference to the regeneration of the patellae of dogs, presented experimental evidence to support the following findings:

"Under adequate mechanical conditions produced by an intact, normally mobile knee joint and its related soft parts, patellar cartilage and bone regenerate after the patella is excised, from young

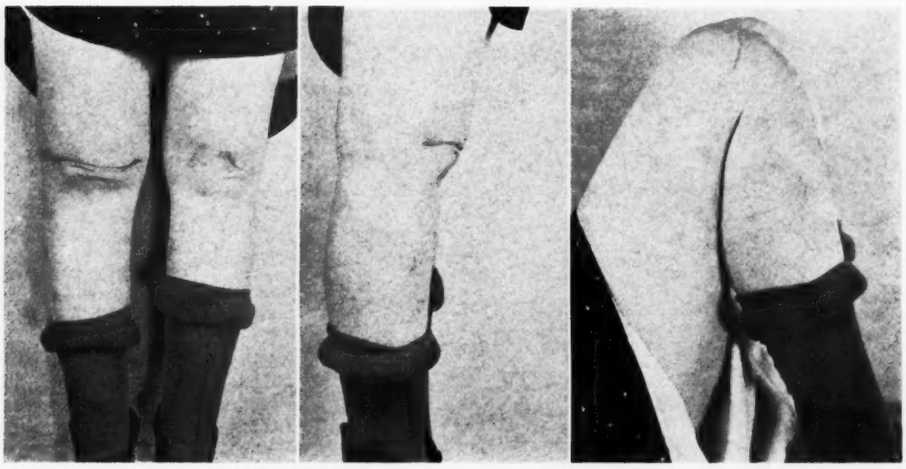
connective tissue cells which had not been destined as specific formers of bone.

"When adequate mechanical conditions are altered by means of



A B C D E

FIG. 8. Case IX. Laboror, age fifty-seven, photographed eight months postoperatively. Left patella excised March 25, 1940. Full function ten weeks. A, it is difficult to identify the affected knee. B, kneeling and full flexion demonstrated. C, body weight easily supported on semiflexed affected limb. D, extension power unaffected limb fifty pounds. E, extension power affected limb 50 pounds.



A B C

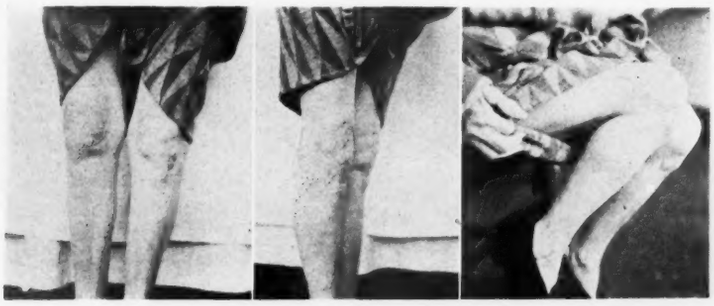
FIG. 9. Case XIV. Housewife, age fifty-three, photographed three months postoperatively. Right patella excised November 12, 1940. A, except for transverse incision, one could not identify the affected knee. B, lateral view demonstrating complete extension. C, complete flexion demonstrated.

immobilizing the knee joint (arthrodesis), with the patella left intact, patellar cartilage and bone atrophy.

"When the patella is excised in toto and adequate mechanical conditions are altered by means of knee joint fixation, patellar cartilage and bone do not regenerate, even with the tendon of the

quadriceps extensor femoris muscle and the patellar ligament united by suture.

"The *adequate mechanical conditions* are a normally mobile,



A B C

FIG. 10. Case XVIII. Elderly woman, age seventy-nine, photographed three months postoperatively. Right patella excised January 16, 1941. A, except for scar, it is difficult to identify the affected knee. B, lateral view demonstrating complete extension. C, full flexion demonstrated.

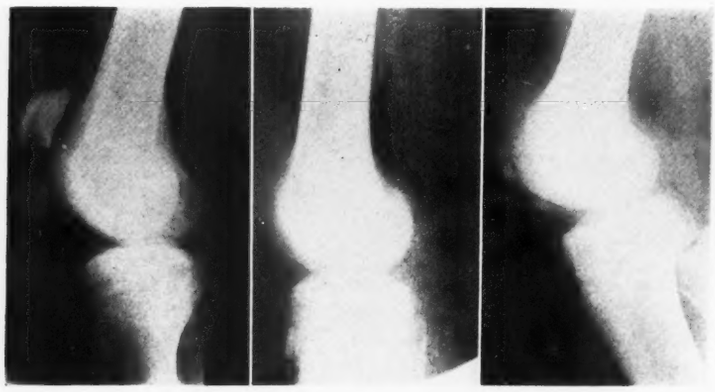
A B C

FIG. 11. Case I. Regeneration of the patella? (Thirty-six months.) A, preoperative *x*-ray left knee. B, same knee one month postoperatively. Notice early patellar regeneration. C, same knee thirty-six months postoperatively. Notice evidence of progressive regeneration. (Areas of bone larger and more dense.) Mass resembling patella can be felt.

exercising articulation with the soft parts replaced, a condition met in the case of a knee joint where the patella is excised and the tendon of the quadriceps extensor femoris muscle sutured to the patellar ligament with quickly absorbable material.

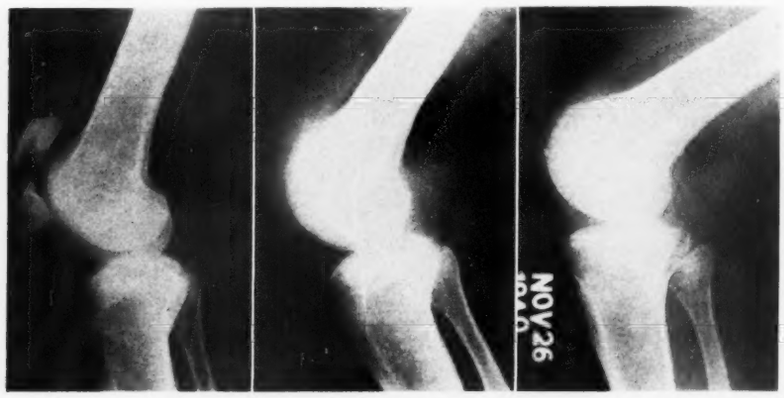
"The patellar bone, therefore, is dependent in origin and structure. It is neither self made nor self supporting. Its genesis and continued existence in actuality are contingent upon the mobility of the knee joint and the pressure and tension, of remittent character,

produced by the activity of the quadriceps extensor muscle through its tendon that passes over the ventral aspect of the lower end of the femur."



A B C

FIG. 12. Case IV. Regeneration of the patella? (Thirty months.) A, preoperative *x*-ray of the left knee. B, same knee one month postoperatively. Note faint shadows representing early patellar regeneration. C, same knee thirty months postoperatively. Notice extensive patellar regeneration. One can feel what resembles a normal patella in this case.

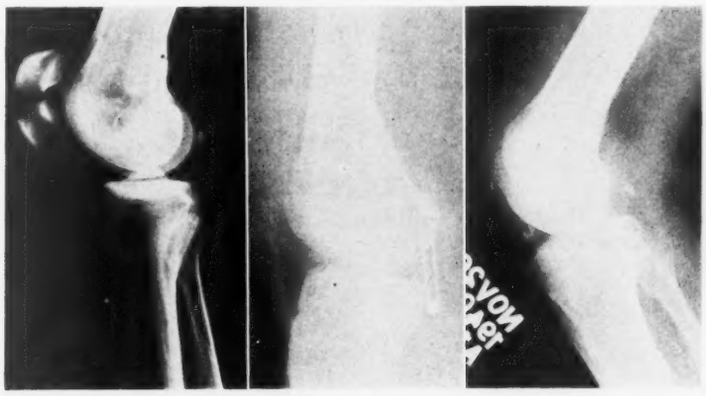



A B C

FIG. 13. Case V. Regeneration of the patella? (Eighteen months.) A, preoperative *x*-ray of right knee. B, same knee one month postoperatively. Note early evidence of patellar regeneration. C, same knee, eighteen months postoperatively. Note progressive regeneration. Patellar mass can be palpated.

In thirty dogs the process of regeneration was studied radiographically and microscopically after a segment of tendon including the entire patella had been removed and the remaining tendon ends reapproximated with chromic gut sutures. It was stated that ten to fourteen days after excision each dog recovered the use of the oper-

ated leg and the knee joint functioned as before the operation. Radiographic evidence of regeneration appeared early (seventeen to sixty days) and progressed rapidly in all dogs.



A B C

FIG. 14. Case VIII. Regeneration of the patella? (Nine months.) A, preoperative *x*-ray left knee. B, same knee one week postoperatively. Note the absence of any suggestion of regeneration this early. C, same knee nine months postoperatively showing patellar regeneration. Patellar mass can be palpated.

A B C

FIG. 15. Case IX. Regeneration of the patella. (Eight months.) A, preoperative *x*-ray left knee. B, same knee one month postoperatively. Note early patellar regeneration. C, same knee eight months postoperatively. Note extensive, progressive patellar regeneration in the relatively short time elapsed. Patellar mass can be palpated.

*X*-ray photographs were presented in the original article showing opacities in the repaired tendon at the original site of the patella, which were assumed to be evidence of regeneration. Though these areas, said to be bone, increased in size and density with time, *x*-ray evidence of complete regeneration of the patella was not demon-

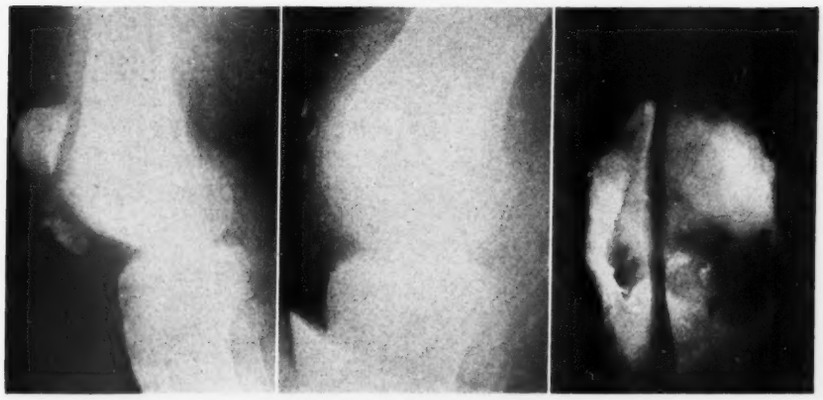
strated. It was not stated whether any of the dogs subsequently developed a complete new patella, but it seems that sufficient evidence was presented to suggest an attempt at patella regeneration.

A B

FIG. 16. Case XVIII. Regeneration of the patella? (Three months.) Seventy-nine year old woman. A, preoperative *x*-ray right knee. B, same knee three months postoperatively. Note evidence of early patellar regeneration in spite of senility.

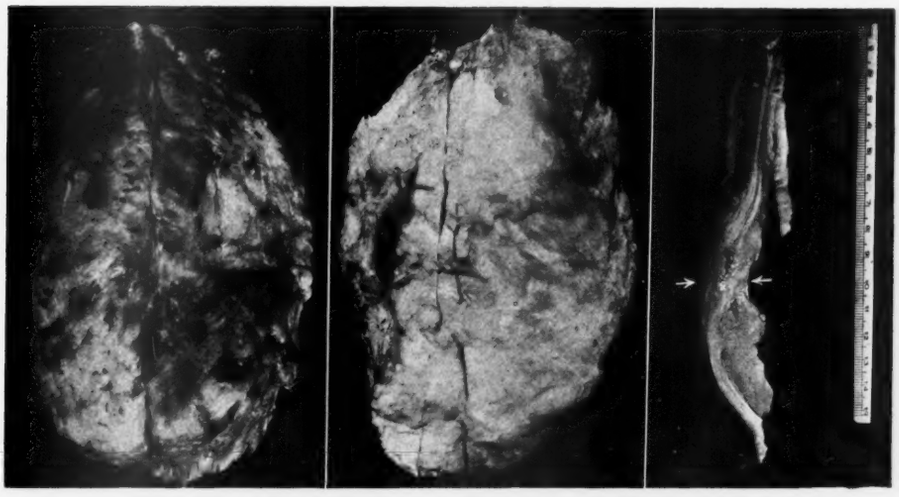
In our series of cases the same opacities, demonstrated as occurring in dogs, are shown by *x*-ray in the repaired human tendon at the original site of the patella. If these shadows are foci of regeneration, it has been constantly observed that radiographic evidence of same appears early and progresses with relative rapidity. In some of our earlier cases (1, 4, 8, 9) a cartilagenous mass conforming somewhat to the patella in shape, size and location, can be felt in the repaired quadriceps tendon. *X*-rays as early as one month postoperatively, show faint but definite irregular areas of density (proved to be bone) in the sutured tendon at the original site of the patella. These so-called areas of regeneration progressively increase in size, number and density with time but in no case (up to thirty-six months) have we been able to demonstrate by *x*-ray a complete new patella. Objective evidence of this suggested regeneration referred to, is furnished in Figures 11, 12, 13, 14, 15, 16, 17, 18 and 19.

Case 11, portrayed in Figures 17, 18 and 19 and referred to several times earlier in this paper, is of special interest. Strangely and sadly enough it was the only private case of the senior author. Because of unfortunate fatal pulmonary embolism it became possible to obtain for gross and microscopic study, the repaired and healed



A B C

FIG. 17. Case XI. Regeneration of the patella? (Seven weeks.) Fatal case autopsied. A, preoperative *x*-ray left knee. B, same knee one month postoperatively. Note marked early patellar regeneration. C, seven weeks postoperatively, *x*-ray anterioposterior through isolated quadriceps tendon. Specimen (fixed) obtained at autopsy. Vertical groove represents defect of section for photographic and microscopic study. Note irregular opacities representing patellar regeneration at this early date. (See Figs. 18 and 19.)



A B C

FIG. 18. Case XI. Quadriceps tendon removed at autopsy seven weeks postoperatively. Tendon repair grossly demonstrated. A, viewed from front. (Vertical defect extending through middle of specimen is the result of postmortem removal of sections for microscopic study.) Excellent repair is demonstrated. B, same as (A) showing repaired articular surface of tendon. The original site of the patella is seen as a relatively small oval depression. C, vertical section of the same tendon showing excellent restoration of continuity in the tendon. Observe bony deposits at original patellar site representing patellar regeneration well advanced as early as the seventh week. Arrows mark site from which microscopic sections were made. (See Fig. 19, A and B.)

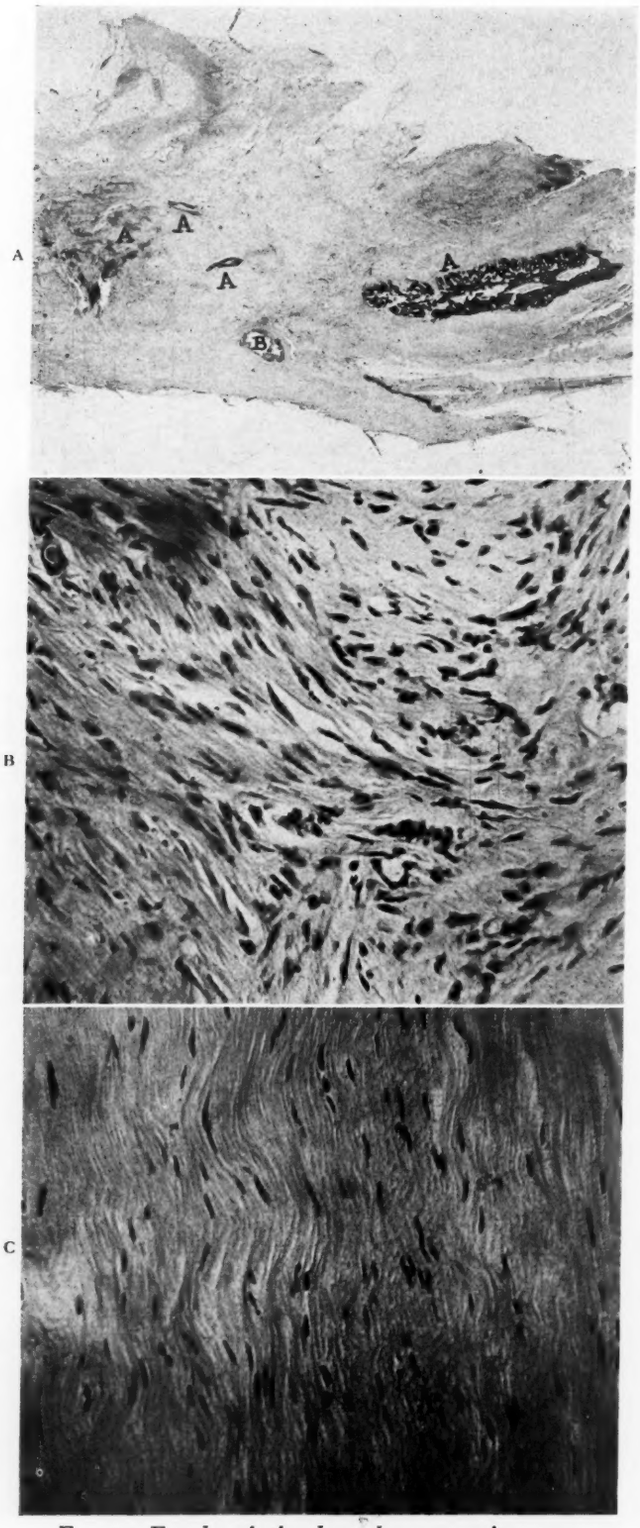



FIG. 19. For descriptive legend see opposite page.

quadriceps tendon from which the patella had been excised forty-seven days previously.

At autopsy the entire quadriceps tendon was widely removed and from studies of the specimen (gross, microscopic and radiographic) several interesting observations were made.

The site of repair of the tendon and expansions was excellently healed by primary intention. Scar tissue had completely and smoothly restored the continuity and there was surprisingly little chronic inflammatory reaction in or about the suture line. (Figs. 18 and 19.)

Upon examining the articular surface of the tendon (Fig. 18B) the original site of the patella could be identified as a smooth oval depression and in this patellar depression, could be seen and felt numerous, confluent, glistening, hard areas of bone suggesting evidence of patellar regeneration as demonstrated by *x*-ray so constantly in our cases.

Microscopic examination of the tendon through the suture line showed a pronounced degree of fibrous tissue proliferation with surprisingly little chronic inflammatory reaction and localized areas of young and growing bone were demonstrated throughout the sections examined. (Fig. 19A.)

## SUMMARY

The authors believe they have demonstrated the superiority of the treatment of fractures of the patella by excision. As far as one can tell by careful examination of the cases, between three and forty-one months postoperatively, function is restored in all of the cases as completely as has been demonstrated in those several cases illustrated by photographs. It is possible to identify the affected knee only by the scar of the incision and the exaggerated prominence of the condyles of the femur. Flexion and extension, stability and power are unaffected by removal of the patella and the patients themselves frankly admit that their limb is as good as before injury.

It occurs to one that loss of the patella exposes the femoral condyles to trauma which may cause serious derangement of the knee joint. This criticism seems valid and though it has not yet occurred

FIG. 19. Microphotographs of repaired quadriceps tendon, Case XI. (See Fig. 18.) A, microscopic section through line of suture showing (A) bone, (B) site of silk suture. Fibrous tissue proliferation throughout. B, view of same area (higher power) showing pronounced fibrous tissue proliferation with practically no chronic inflammatory infiltration. C, for control purposes, same power as (B) section of normal quadriceps tendon from which the patella was excised postmortem. (See Fig. 1D.)

in any of our cases, would constitute a serious objection to the procedure were it not for the fact that regeneration of the patella probably takes place and when and if completed, should eliminate any unusual predisposition to injury.

## CONCLUSIONS

1. The nonoperative treatment of fractured patella with separation of fragments is in general undesirable and unsatisfactory.

2. Arthrotomy with osseous suture as was suggested and advocated by Lord Lister in 1877, has been the treatment of choice for the past fifty years.

3. Though bony union, more rapid repair and better function resulted following arthrotomy and suture, much is left to be desired; and though a useful limb is as a rule obtained, in most instances considerable permanent functional loss persists.

4. Complete excision of the patellar fragments in those cases of fracture requiring operation is superior to any other treatment for the following reasons: (a) The operation is simpler and less time consuming; (b) convalescence is smoother and more rapid; (c) the period of hospitalization and disability is appreciably less; (d) earlier, more complete functional recovery is the rule; and (e) the late complications of osseous suture are eliminated.

5. In those cases from which the patella has been removed, the efficiency of the knee joint is in no way impaired. The range and rapidity of movement and the power is in no way inferior to that displayed in the opposite, intact limb.

6. There is evidence suggesting that following removal, regeneration of the patella occurs at its original site. If true, any attributed protective function would be eventually restored.

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## DISCUSSION

J. HUBER WAGNER (Pittsburgh, Pa.): Unfortunately, I got in a little late and so did not see more than the tail end of this beautiful movie. I have had the privilege of reading this manuscript of Dr. Dobbie's, however, and I do not know how much he was able to give of it, but I want to assure you that when it is published it will certainly be worth reading. It is one of the finest papers I have had the privilege of reading.

I am a little like the late and beloved Will Rogers, so far as this particular subject is concerned, for all I know about it is what I have read in the papers. I have not had any practical experience save, of necessity, on several occasions when I have had to take out some comminuted fragments of one of these cases of patella fractures.

Strange to say, at first, not knowing the work that had been done on this, I was very much worried concerning the end results, and was surprised to find that these patients do very well with a half and sometimes as little as a third of the normal patella.

Having read this paper, and seeing the end results as shown here, has certainly removed all the skepticism that I might have had concerning the wisdom of excising the patella. I do not know whether in the future, when I get a transverse fracture, I will be courageous enough to take it out—I am still a little slow on that—as we have had some very good results in our cases of fractured patella cases, believing that the essential thing after fixation was early function, i.e., both active and passive motion of the knee joint at an early date.

In Dr. Dobbie's cases, his average stay in the hospital in the twenty-one cases was about twenty-two days. I may be wrong about that figure. Our

average stay in the hospital is about the same. We get our patients up early and start them going.

This method, however, certainly shortens the convalescent period. As to the method or approach whether the transverse or the vertical incision is preferable, personally I believe that perhaps the vertical incision is the one of choice, as it does not interfere with the circulation, which is often a factor especially in elderly people.

As I said, I have no actual experience with this method, but it strikes me that probably the use of black silk is the suture material of preference. It has given us good results in many other joint operations and it certainly is well tolerated here.

Dr. Dobbie's paper shows a great deal of work and research from the historical point of view. This operation was used first of necessity and now as a matter of choice. Perhaps in the future we will lean a little more toward the employment of this particular method of excision of the patella at the time of fracture.

Robert I. Harris (Toronto, Ontario): It seems to me this is one of the most important contributions that has been made to our program, because it has demonstrated in a convincing manner that Brooks' claims and statements are true, claims which many of us had difficulty in believing, even though they were supported by the confirmation of Hey Groves.

We have had a brief experience with the method of treating fractures of the patella Immediately after Brooks published his paper, some of our fractures of the patella were treated by excision. Our results were unfortunate in that all ended with limitation of movement of the knee joint, some with gross limitation of the movement of the knee joint.

Why that was, I am unable to say, but Dr. Dobbie's presentation will lead us, I am sure, to return to the method with the hope and assurance that we can solve the problem of limitation of movement of the knee.

There can be no doubt that there are certain types of fracture of the patella which are difficult to treat by any method which attempts to repair the fracture, the badly comminuted case being the outstanding example. Moreover, I believe this presentation has demonstrated that it can be extended into another field, namely, the field in which osteo-arthritis involves chiefly the patella, giving rise to a painful joint which is disabling out of all proportion to the osteo-arthritic lesion which is present.

I recently have had occasion to remove a patella for such a lesion, with the result which to date is extremely satisfying

Thomas H. Peterson (Boston, Mass.): I can add just a little in regard to the dislocation of patellas. I have had only one or two cases in which they have been removed, but the operation is far more satisfactory than any of the transplants which we might have used, and even in the transplantation of the patella tendon. I think we are going to find that this

procedure is going to be a great help along with our other procedures in treating the dislocating patella.

PHILIP D. WILSON (New York City): I can echo what has been said already, and particularly because I have seen localized osteo-arthritis in several old cases which previously had had fractured patellas, had been sutured with excellent results which persisted over a period of years, and then eventually developed this localized type of osteo-arthritis between the femur and the patella. The relief of this symptom is by excision of that patella.

There is one thing that is important to point out, that is, that the patella will regenerate again in a good many of these cases. You will not get the same sized patella as originally, but you will get ossification developing which will make a considerable show.

I do not believe that is a harmful thing; I am sure Dr. Dobbie has seen this. I do not think it is at all harmful, nevertheless you should not be surprised if a year or two later you find you have a new patella.

ROBERT P. DOBBIE (closing): Briefly, I do not know why Dr. Harris did not get good results equal to ours. I am sure we cannot excise patellas any better than he and his group can. Our results have all been very excellent; so excellent that it is hard to believe.

In reply to Dr. Peterson's remarks, a British surgeon, I think it is Tippet, advises very strongly against operating on a recurrent or dislocating patella by excision. It makes them worse, he says, not better. He tried it in two cases, and gives that as one definite contraindication.

In commenting on Dr. Wilson's remarks on regeneration, I dare not say much about regeneration. I thought I knew something about it, but the more I think about it the less I know about it. In seven of our cases they began to show at the end of the month, new bone in the quadriceps tendon at the site of the patella. In four of the cases they have what feels like a patella, a cartilaginous mass. There are a lot of things I do not know about this, and whether it is a regeneration or an effort at regeneration, I cannot say.

# THE LOCAL THERAPEUTIC EFFECT OF SULFATHIAZOLE

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THE surgical management of open wounds and surgical infections by chemotherapy is by no means a new procedure.

The advent of the sulfonamide group of chemicals has recreated a widespread interest in one of man's first surgical problems. Today medical science is fulfilling Ehrlich's early prediction of the discovery of chemicals having bactericidal and bacteriostatic properties without deleterious effect upon human tissues.

Our early work with the sulfonamide drugs involved the treatment of general and local wound infections by direct application of the crystalline chemical at the site of the infection. We became impressed by the apparent absence of any gross destructive or irritative effect upon human tissues and the rapid disappearance of the infection. In view of the abundance of heavily contaminated traumatic wounds and compound fractures, which come to our service, we conceived the idea of preventing the development of infection in these cases by the local administration of the drug during the time period of contamination.

We were further impressed by the excellent work of Jensen following the local application of sulfanilamide crystals in the treatment of compound fractures.

Our work in this field constituted a study of the clinical behavior of sulfathiazole* in the treatment of compound wounds, compound

* The supply of sulfathiazole was made available by a grant from the Winthrop Chemical Company.

fractures (recent and old), various types of surgical wounds and infections and use of the drug intraperitoneally in abdominal surgery.

In our present paper we are presenting the results of the local application of sulfathiazole in fresh compound wounds, compound fractures and simple fractures requiring operation.

Having little available information as to the behavior of the drug, when applied locally into wounds, our procedure and technic were carried on with considerable caution in order to evaluate the drug's real worth.

In all cases cultures of the wounds were taken immediately following inspection. Positive cultures representing a wide range of pathogenic organisms, including the various types of gas bacillus, were reported from the cases of contaminated and potentially infected wounds.

However, it was found that during the period of contamination (four to six hours after injury) the number of organisms recovered by routine bacteriological studies were few. Cultures taken from the compound fractures were positive in 50 per cent of the cases and in soft tissue wounds 32 per cent were positive.

It is quite apparent that the pathogenic contaminators during the above period had not as yet reached a reproductive stage in which they were sufficiently numerous and virulent to present evidence of invasion or active infection.

The above findings coincide with the already existing opinions regarding the value of débridement during this period when the organisms are few in number and low in invasive properties. Débridement of contaminated wounds, as practiced in recent years, has contributed much toward the prevention of wound infection. Its practice as a preliminary phase of surgical management of wounds should continue as a standard principle in treatment.

During our present study, we have changed our usual technic of handling wounds and compound fractures in only two respects: (1) application of sulfathiazole crystals directly into the wounds, and (2) complete closure of all wounds without drainage.

In all cases, the drug was applied locally and distributed throughout the cavity by means of a sterile cotton applicator or sterile gloved finger. It is important that the powder reach all tiny recesses, fissures and corners. The extent of the wound and the type and condition of the tissues involved determined the quantity of drug to be implanted.

The crystals were implanted as dispensed from the original container prepared in 5 and 10 gr. powder papers. No attempt was made to sterilize the crystals prior to their use, even though this can be effected without chemical change to the drug.

In a number of cases, surgical repair of the damaged parts was delayed by shock, hemorrhage, heart, lung and other complications. Sulfathiazole was applied locally as a prophylactic agent in these cases with operation at a later date.

Whether complete repair and reduction were performed immediately, or delayed, all wounds were closed completely without drainage and immobilized by splints when indicated. Our results have been most gratifying as shown by the following tables. (Table 1.)

The first series consisted of fifty-eight compound fractures, as listed in Table 1. All wounds were of major proportions concerning their locations, with considerable muscle as well as other soft tissue damage. Open reduction, when indicated with internal fixation, was performed immediately if the patient's general condition was satisfactory, or delayed if necessary by shock, hemorrhage or other complicating factors. In all cases, however, a large quantity of sulfathiazole was diffused thoroughly throughout the wound and about the fracture site. This was followed by immobilization of the injured parts using plaster splints whenever needed. An operative procedure was found necessary in 89.6 per cent of these compound fractures.

It will be noted that only 50 per cent of this series showed cultures positive for pathogenic organisms. This observation is not unexpected in view of the fact that almost all of these cultures were taken within six hours of the time of injury. At this period the infective bacteria had not yet begun to multiply nor had they become invasive to any great degree. It is during this latent period that the local application of sulfathiazole has the greatest prophylactic value.

Analysis of the percentage figures of infection (10.3 per cent) developing in compound fractures after using sulfathiazole, at first glance does not appear impressive. Of the six patients developing infection, two occurred in severe leg injuries in which the circulation of the distal portion of the limb was entirely destroyed. Gangrene resulted necessitating amputation at the fracture site. Pathogenic organisms were cultured from the wound sites and there was a liquefaction necrosis of the gangrenous tissues; for this reason, we classified these two cases as infected. It seems unfair to expect the drug to prevent the development of bacteria in completely necrotic

tissue which has absolutely no normal defensive mechanisms. In both cases, the viable tissues proximal to the site of injury, were healthy and showed no clinical evidence of infection. Following amputation, the stumps healed with remarkable rapidity. We

TABLE 1

CONTAMINATED COMPOUND FRACTURES—PROPHYLACTIC LOCAL USE OF SULFATHIAZOLE

| Compound Fracture of | No. of Cases | Positive Culture on Admission | Deaths | Operations | Infections | Toxic Reactions | Results |
|---|---|---|---|---|---|---|---|
| Femur | 2 | 1 | 0 | 2 | 1 | 0 | Infected case had loss of circulation of lower leg with gangrene necessitating amputation. Infection minimized. |
| Tibia and fibula | 14 | 7 | 0 | 14 | 1 | 1 microscopic hematuria<br>1 drug fever and rash<br>2 delayed union | Infected case had loss of circulation below fracture site with gangrene necessitating amputation. Infection minimized. |
| Humerus | 2 | 2 | 1 | 1 | 1 | 0 | Infected case developed gas gangrene after drug was discontinued, and died. |
| Radius and ulna | 2 | 1 | 0 | 1 | 0 | 0 | |
| Tarsal | 1 | 1 | 0 | 1 | 0 | 1 delayed healing | Marked destruction soft tissues foot. |
| Metatarsal | 1 | 0 | 0 | 1 | 0 | 0 | |
| Metacarpal | 1 | 0 | 0 | | 0 | 0 | |
| Phalanges | 27 | 11 | 0 | 23 | 2 | 2 delayed healing<br>1 headache, vomiting and microscopic hematuria | One infected case developed infection only after oral drug was stopped—no local drug. Second infection apparently failure of drug to prevent infection. |
| Skull | 3 | 2 | 3 | 3 | 1? | 1 hematuria, hepatitis, renal failure? | All 3 cases had severe brain damage and died within several days. Infected case developed mastoiditis. |
| Face bones | 5 | 3 | 0 | 5 | 0 | 0 | |
| Total | 58 | 29 | 4 | 52 | 6 | 9 | |
| Per cent | .. | 50 | 6.9 | 89.6 | 10.3 | 15.5 | |

propose, therefore, to eliminate these two cases as being failure of sulfathiazole to prevent infection in compound fractures. A third patient sustained a fractured skull compounded through the mastoid and middle ear. Local application was impossible in this instance and we feared to give extremely large doses orally or intravenously

due to already impaired vital signs. We believe that the development of mastoiditis was not due to a failure of the drug *per se*. An impossible situation existed in this case with severe shock, severe brain trauma and renal failure.

By removing these three cases from our figures, the corrected incidence of infection drops from 10.3 per cent to 5.4 per cent. This value is extremely low for a series of compound fractures and it becomes particularly significant in view of the fact that the entire group was composed of consecutive cases as they were admitted to our service and not a selected series of patients. The majority of these fractures were produced by crushing injuries in mining accidents with considerable comminution of the fractures and severe trauma of the soft tissues.

The remaining three cases of infection require some comment. One compound fracture of a finger developed a mild infection after the oral use of the drug was discontinued; sulfathiazole was not applied locally at the time of injury, but local applications following the development of the infection controlled it rapidly. The second case was one of a compound fracture of thumb. This wound continued to drain a purulent exudate for several weeks in spite of repeated local applications of the drug. We are unable to explain the failure of prophylaxis here. The third patient sustained a compound fracture of the humerus in the proximal third with complete traumatic amputation. The muscles of upper arm and shoulder were badly mutilated and Clostridium welchii was reported from cultures. The patient received large doses of sulfathiazole locally and by mouth. His condition improved materially during the first four hospital days. At that time, the drug was discontinued orally and within twelve hours a virulent gas gangrene of shoulder and chest developed which was fatal within another twelve hours in spite of all treatment. Although cultures from five other cases showed Clostridium welchii this is the only one which developed gas gangrene following prophylactic use of the drug. It is our belief that large doses of sulfathiazole given both locally and orally within three or four hours of injury and continued for nine to fourteen days will prevent many cases of gas gangrene. Sulfathiazole has not been so effective in the treatment of active gas gangrene in our experience.

The wounds of the other fifty-two cases in this series healed without infection, in a manner approaching primary union, save for an occasional discharge of a clear, nonpurulent, serosanguineous exudate.

The constitutional and local reactions from the drug were closely observed in all the cases presented in this series. Wound inspections were made to observe any reaction, discharge, progress of healing, lymphangitis, adenitis and swelling; also frequent urine analyses, nonprotein nitrogen observations, and frequent blood level estimations were obtained. Careful observations were made for any local or general toxic manifestations, which, if they occurred, were given

TABLE II

CONTAMINATED TRAUMATIC WOUNDS—PROPHYLACTIC LOCAL USE OF SULFATHIAZOLE

| Traumatic Wound of | No. of Cases | Positive Cultures on Admission | Deaths | Operations | Infections | Toxic Reactions | Results |
|---|---|---|---|---|---|---|---|
| Scalp | 4 | 0 | 1 | 0 | 0 | 0 | Death occurred from other injuries and complications |
| Face | 4 | 2 | 0 | 3 | 0 | 1 delayed healing | Delay due to persistent serum collection |
| Neck | 2 | 2 | 0 | 1 | 0 | 0 | |
| Shoulder | 1 | 0 | 1 | 0 | 0 | 0 | Death occurred from complicating injuries and cerebral embolus |
| Arm | 2 | 1 | 0 | 2 | 0 | 0 | |
| Forearm | 1 | 0 | 0 | 0 | 0 | 0 | |
| Hand | 4 | 1 | 0 | 3 | 0 | 1 delayed healing | |
| Fingers | 5 | 0 | 0 | 4 | 1 | 1 delayed healing | Infected case of anaerobic streptococcus resistant to drug |
| Rupture urethra | 1 | 0 | 0 | 1 | 0 | 0 | |
| Penis and scrotum | 1 | 1 | 0 | 1 | 0 | 0 | |
| Anal sphincter | 1 | 1 | 0 | 1 | 0 | 0 | |
| Thigh | 2 | 2 | 0 | 2 | 0 | 2 delayed healing | |
| Lower leg | 1 | 0 | 0 | 1 | 0 | 0 | |
| Foot | 2 | 0 | 0 | 2 | 0 | 1 delayed healing | |
| Total | 31 | 10 | 2 | 21 | 1 | 6 | |
| Per cent | | 32.2 | 6.5 | 67.8 | 3.2 | 19.3 | |

immediate consideration and treatment. As noted in Table 1, 15.5 per cent of cases showed one or more toxic reactions. Except in one instance, these reactions were of a mild character and continued administration of the drug was possible. The exception was the case of the patient with a compound fracture of skull with meningitis who developed a toxic hepatitis with jaundice and died. It is highly questionable whether death was due to toxic reaction from sulfathiazole, however, as the severe brain injury plus meningitis and mastoiditis were sufficient cause for death. The other three deaths in this

series were due to severe brain damage following compound fracture of skull (two cases) and gas gangrene of shoulder (referred to previously). (Table II.)

The second group consisted of thirty-one soft tissue wounds, similar in all respects to those listed in Table I, except for the presence of a complicating fracture. Treatment and observations were instituted in a similar manner. As was found in the previous group the number of positive cultures upon admission during the period of contamination was again found to be low—32.2 per cent. In 67.8 per cent of cases the wounds were of sufficient magnitude and gravity as to require an operation for repair of the parts. Healing comparable to primary union occurred in twenty-five cases of this series of thirty-one. Five of the cases of this group showed a moderate delay of healing due to a collection of serum within the wounds or to a loss of soft tissues to such an extent as to make complete repair of the wound impossible. Only one case of this series showed infection. This wound involved a finger. Despite the continued local application of sulfathiazole following the usual technic of repair, a superficial and persistent infection developed. The exudate was purulent and foul-smelling and repeated cultures showed an anaerobic streptococcus. Response was finally obtained after six weeks' application. It is our feeling that this organism is highly resistant to the drug. The two deaths which occurred in this series were caused by complicating injuries, not associated with the soft tissue wounds, which were treated with local applications of sulfathiazole.

There were no general or systemic toxic reactions in this group, due, primarily to the fact that only a few cases received the drug orally (in addition to local application) and in small doses.

In Groups I and II we have noted twelve cases of delayed healing of the wounds and two cases of delayed union of the fractures. We cannot definitely ascribe the delay of healing and union to a toxic reaction of the drug; however, we feel these findings should be mentioned and offer a field for further investigation. (Table III.)

Group III constituted a series of simple fractures which were operated upon because of gross displacement of the fragments. These cases represented clean, noncontaminated areas. The implantation of the chemical served as a prophylactic agent in maintaining surgical asepsis of the wound as well as a means of investigating wound changes. The amount of the drug implanted depended upon the size and character of the incision. The incisions were closed completely and healed by primary union. There were no infections

in this series. There were three cases of delayed formation of callus; this cannot be definitely ascribed to the drug but should be kept in mind as a possibility. There were no deaths in this series and no general systemic reactions to the drug.

TABLE III

SIMPLE FRACTURES REQUIRING OPERATION—PROPHYLACTIC LOCAL USE OF SULFATHIAZOLE

| Simple Fracture of | No. of Cases | Positive Cultures on Admission | Deaths | Operations | Infections | Toxic Reactions | Results |
|---|---|---|---|---|---|---|---|
| Femur | 8 | .. | 0 | 8 | 0 | 2 delayed union | |
| Tibia | 5 | .. | 0 | 5 | 0 | 1 delayed union | |
| Patella | 3 | .. | 0 | 3 | 0 | 0 | |
| Malleolus | 2 | .. | 0 | 2 | 0 | 0 | |
| Metatarsal | 1 | .. | 0 | 1 | 0 | 0 | |
| Humerus | 2 | .. | 0 | 2 | 0 | 0 | |
| Clavicle | 1 | .. | 0 | 1 | 0 | 0 | |
| Total | 22 | .. | 0 | 22 | 0 | 3 | |
| Per cent | .. | .. | 0 | 100 | 0 | 13.7 | |

In our discussion of these preceding series of cases, we shall confine our remarks to the local and general reactions following the application of sulfathiazole locally. The toxic reactions of the drug following oral administration have been reviewed by numerous writers. We shall not discuss this phase of the problem in this paper except to state that in the series of cases presented, the only serious toxic reaction which occurred was the development of a toxic hepatitis in a case of compound skull fracture referred to previously.

We attribute the infrequency of serious reactions (following oral administration) in our cases to the policy of insisting that all patients receive an abundance of fluid by mouth and, when indicated, saline and glucose intravenously. By this means the drug is eliminated rapidly and at the same time the urinary concentration of the drug is kept at a low level decreasing the possibility of forming renal calculi and tubular concretions. All patients also received, unless contraindicated, high protein and high vitamin diets with supplementary administration of vitamin C.

Recent experimental work by Martin, Fisher and Thompson have indicated that several of the intermediary products of protein metabolism and vitamin C besides being natural detoxifiers of body poisons, also act to reduce the toxicity of the sulfonamide drugs and

at the same time enhance their therapeutic effectiveness. The rôle of proteins and vitamin c in promoting the natural processes of wound repair is well known.

There has been considerable discussion regarding the exact mode of action of the sulfonamides. For the present, they can best be described as having a bacteriostatic effect.

Lockwood, in a recent article, stated that "the therapeutic result in a given case of established or threatened infection will depend upon the adjustment of three principal variables; namely, the concentration of sulfonamide maintained in the immediate environment of the bacteria, the mobilization of the cellular defense (which of course varies in different tissues), and the concentration of sulfonamide inhibitor substances."

The principles of treatment, which we have used in this series of cases, utilize each of these factors as favorably as possible. By applying the drug locally and closing the wound without drainage, a high local concentration of sulfathiazole is maintained in the immediate region of the contaminating bacteria. This concentration is much higher than can be secured by oral administration and as the drug is absorbed rather slowly over a period of four to six days a constantly high local concentration is obtained.

It has been shown experimentally that peptone, p-aminobenzoic acid and other protein degradation products act as inhibitor substances to the action of the sulfonamides, restricting the chemotherapeutic effectiveness of the drug to a marked degree. It has also been shown that these inhibitor substances are derived from the decomposition of injured, nonviable tissues, such as are always present in traumatic wounds, and from the degenerating cell bodies of the bacteria themselves. A thorough débridement of all wounds is, therefore, important to remove the source of these inhibitor substances. It is also important that the sulfathiazole be applied during the time period of contamination before the bacteria have an opportunity to multiply to a state in which they may of themselves become an inhibitor substance.

We have found novocaine to be an inhibitor substance; hence the use of local anesthesia is advised against in all cases in which sulfathiazole is to be used as prophylaxis against infection.

If nonviable tissues are removed from the wound and the proliferation of bacteria is prevented, it is obvious that the natural defense mechanism of the host will be able to function to the best advantage.

At the outset of our studies we were particularly concerned regarding the effect of sulfathiazole on the soft tissues themselves to which the drug was applied. The absence of local irritation to the

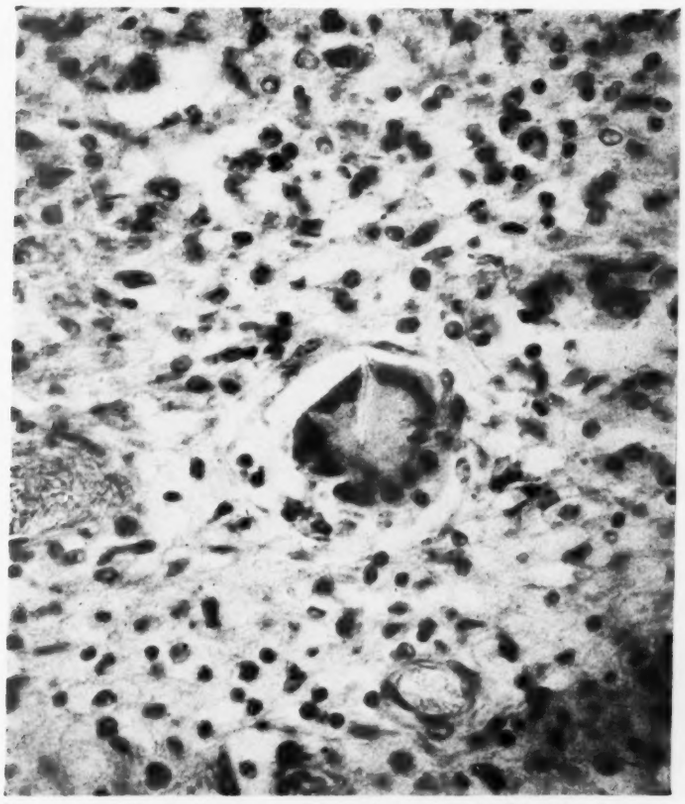

FIG. 1. Foreign body giant cell reaction around sulfathiazole crystal in granulation tissue. (High power.)

wound has been very striking. For the most part the wounds have healed completely in a normal period of time without undue accumulations of serum and without any unusual production of scar tissue. We have had occasion to examine microscopically sections of tissue to which sulfathiazole had been applied (taken from cases of delayed wound healing, removal of bone plates, etc.). In no instance was there any microscopic evidence of any interference with the normal processes of healing. The granulation tissues had a normal appearance; there was adequate production of collagen, and the capillaries and fibroblasts were proliferating normally. We are thus unable to account for the occasional case of delay in healing.

One of the sections studied showed a peculiar phenomenon. The tissue was a biopsy of granulation tissue taken from a case of healing

osteomyelitis. The microscopic picture resembled ordinary granulation tissue except for the presence of occasional scattered foreign body giant cells, each of which surrounded what was presumably one or more crystals of sulfathiazole. There was no other cellular or histologic change to differentiate this section from any of the others studied. In none of the specimens was there any unusual cellular reaction to indicate irritation aside from the giant cells as mentioned. (Fig. 1.)

Further evidence of the absence of local irritation from direct application of the drug crystals has been obtained from our abdominal and joint surgery. In several cases of two-stage intestinal resections and in several autopsies, we have observed the absence of any unusual intraperitoneal adhesions. Traumatic lacerations in a number of cases involved joint capsules. Following healing of the wounds, the joint motions were found to be restored to normal.

No subject of the type presented in this paper would be complete without comprehensive bacteriological studies. The problems which are presented by these studies are numerous and will require further experimental investigation. A thorough bacteriological study of these wounds, many of which show mixed infections, may help to standardize the selection for treatment of one or more of the various sulfonamide drugs as the bacteriological study may indicate.

Experience with a great number and variety of cases enables one to recognize early toxic manifestations of the drug and to differentiate the toxic lesions from other allergic reactions and acute skin dermatoses. Certain of our cases (in other fields of surgery to be reported in a later paper) have proved very susceptible to local and oral administration of sulfathiazole regardless of the quantitive factor or time period of administration. If a patient is sensitive to the drug, he will obtain just as severe a reaction from a small dose as from a large one. This observation has been made independently by several of the clinicians outside of our own group. We believe, therefore that if sulfathiazole is to be used at all, it should be used in adequate dosage so as to secure the full chemotherapeutic effect. Only two patients of our total of some 500 receiving the drug developed toxicity to such a degree that we were forced to discontinue the use of the chemical.

In view of the encouraging results which we have obtained to date following the local use of sulfathiazole to wounds during their period of contamination, we believe that these studies should continue. It is suggested that this method of treatment of wounds may

serve as a most valuable factor in the prevention of infection and the saving of human life in military and war injuries.

## CONCLUSIONS

1. The results of the local use of sulfathiazole in compound wounds, compound fractures and simple fractures requiring operation have been presented.

2. Reduction in the incidence and severity of infection in these wounds was demonstrated.

3. Toxic manifestations following the local use of sulfathiazole was discussed.

4. The supposed mode of action and recommendations regarding treatment have been made.

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# TREATMENT OF FRESH TRAUMATIC WOUNDS

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IN a previous publication[1] the results of an experimental evaluation of methods of initial treatment of fresh contaminated wounds was reported. This report was based upon two groups of experiments carried out in rabbits. In one group, a representative series of bacteriocidal agents "antiseptic solutions" were placed in incisions and injected into the subcutaneous tissues. These solutions consisted of 70 per cent alcohol, tincture of iodine, tincture of green soap, ether and three of the commercial preparations most commonly employed in the United States. The tissues of areas of incision and sites of injection were examined microscopically. In each instance there were demonstrable degrees of tissue injury varying from edema and cells with pale staining nuclei to gross necrosis with abscess formation. Ether caused the least and the tincture of green soap the most severe tissue injury. In the same way the effect of isotonic salt solution and of sulfanilamide upon tissues was determined. Neither agent caused demonstrable injury to tissues.

If the bacteriocidal agents always rendered wounds free of bacteria, the injury to the tissues caused by them would be a relatively unimportant consideration. The failure of these antiseptic solutions to prevent infection of contaminated wounds was demonstrated by the second group of experiments. Compounded wounds with fractures of the radius were inoculated with mixed cultures of hemolytic colon bacillus, Staphylococcus aureus and hemolytic streptococcus. These wounds then received a thorough application of one of the antiseptic solutions enumerated above and were closed without drainage. Suppuration occurred in the majority of wounds and in many instances the fractures failed to unite.

In another series in which identically compounded and inoculated wounds were irrigated copiously with isotonic salt solution and the tissues covered with sulfanilamide powder there was no suppuration. All wounds healed *per primam* and all fractures united normally.

From these experiments it may be concluded that (1) chemical agents capable of destroying bacteria also devitalize or destroy tissue cells; (2) antiseptics do not render all contaminated wounds free of bacteria; (3) sulfanilamide implanted directly into wounds does not injure tissue cells significantly; (4) isotonic salt solution does not injure tissues; and (5) copious mechanical washing of contaminated wounds with isotonic salt solution followed by the topical application of sulfanilamide powder was much more effective in preventing infections than the application of antiseptic solution and did not alter the normal reparative processes.

These experimental observations merely confirm clinical impressions held by many surgeons.

Also reported in a previous publication were the results obtained in twenty-five consecutive cases with major fresh wounds treated by (1) thorough débridement, (2) copious washing with salt solution, (3) implantation of sulfanilamide powder, and (4) primary closure in all but two cases. All cases received this treatment within eight hours of the time of injury and in twenty of the twenty-five cases there was good evidence from history or by fact that soiling of the wounds had occurred either by penetration of a foreign body or by exteriorization of bone. In eighteen cases excised tissue was cultured and from fourteen positive cultures were obtained.

TABLE 1

| Type | No. | Result | | |
|---|---|---|---|---|
| | | Primary Infection | Healing per Primam | Healing Delayed* |
| 1. Compound fractures | 14 | 0 | 6 | 8 |
| 2. Major lacerations | 9 | | | |
| 4 severed tendons | | | | |
| 1 traumatic amputation of arm | .. | 0 | 7 | 2 |
| 3. Extensive shot gun wounds | 2 | 0 | 0 | 2 |
| | 25 | 0 | 13 | 12 |

* Devitalized skin edges separated and healed by granulation.

The series consisted of fourteen compounded fractures of major long bones, nine major lacerations and two shotgun wounds received at close range. The results are briefly summarized in Table 1. Not one patient in the entire series developed a primary infection or a subcutaneous suppurative process and in thirteen or slightly more

than 50 per cent of cases the wounds healed *per primam*. Both shotgun wounds, one of the thigh and one of the flank, were left open because it was impossible to close them after the torn wound margin had been excised. In eight of the fourteen cases with compound fractures and in two of the nine with major lacerations there was failure of primary healing and separation of portions of the approximated skin edges. This we attributed to devitalization and disturbed circulation of the edges of the flaps as a result of the original trauma and to tension. In all but one of these cases retraction of the flaps left only small superficial surfaces which healed by granulations. All fractures in this series united and in no case did osteomyelitis develop. One compound fracture of the tibia recompounded when the skin flaps retracted. As soon as this occurred the portion of the crest of the tibia which was exposed was excised and the flaps re-approximated. Healing with no appreciable retraction followed. When a skin flap evulsed from the crest of the tibia is sutured, it is stretched over dense bone from which there is no angioplasia and healing is dependent entirely upon the small surface of skin-edge contact with the other flap. To provide a wide contacting surface capable of immediate angioplasia and incidentally to lessen tension on the flaps much of the underlying crest of the tibia was cut away with a chisel in a recent case and primary healing resulted.

## PLAN OF TREATMENT

The general plan followed in the treatment of these patients consisted first of all in the immediate control of hemorrhage and the rapid alleviation of shock when these conditions were present. Examination and other forms of therapy were deferred until there had been a satisfactory recovery from shock. There followed then a complete evaluation of the injuries. This included roentgenograms as indicated and detailed examinations for evidences of loss of function of individual tendons and nerves. Inquiry into the possibility of and special examination for evidence of injuries of the urinary bladder and other hollow and solid viscera were made when indicated. Some form of anesthesia, local, spinal or general, was then administered and the wounds cleaned and débrided.

In the compound fractures in which one of the fragments protruded through a laceration of the skin no attempt was made to replace this fragment until it had been thoroughly cleansed. We believe that this principle should be followed whenever facilities for

thorough cleansing are immediately available. A fragment which has been exteriorized is always soiled and the soft tissue bed from whence it emerged is often either totally or relatively sterile. Therefore, cleansing the fragment before replacing it accomplishes the major act in preventing infection and also avoids contamination of the soft tissues. Before the exteriorized fragment was cleansed the skin for a wide area about the wound was rendered surgically clean by scrubbing it with a sterile hand brush for three or four minutes with a stream of sterile water and green soap constantly flowing over the area. The bone was then washed by gentle brushing of all surfaces with a new sterile brush, while normal salt solution (and only salt solution) was constantly poured over it. Solutions other than saline such as soap and antiseptics were used only in preparing the skin and were never permitted to come in contact with the tissues.

In those cases in which the soiled fragment had been replaced before the patient came into our hands we exteriorized this fragment after the skin had been cleansed and washed it as described above.

Before replacing the fragment in either case all parts of the wound were irrigated with large quantities of normal salt solution. It must be emphasized at this time, as it will be repeatedly, that these irrigations must be copious, using many liters of saline. To be successful the principle of mechanically washing contaminants from the tissues necessitates the use of large quantities of saline, washing in and out of every recess of the wound. The wound should be retracted as necessary to expose its entire extent and all surfaces should be gently agitated with gauze while the solution is flowing over them.

The fragment was then replaced and all torn and devitalized bits of fat, muscle and fascia excised. Because crushed skin does not heal readily and often separates, the crushed and devitalized margins of the skin flaps were excised whenever feasible. The wound was again copiously irrigated with normal salt solution, its surfaces covered with a thin layer of sulfanilamide powder and the skin closed, usually without drainage.

The fractures were reduced through the open wound in most instances and after skin closure in others. It is our opinion that if these fractures have been thoroughly cleansed and prepared, as outlined above, they may be handled essentially as clean simple fractures. This applies to the use of metallic and other foreign material for internal fixation. Whenever indicated we have made use of internal fixation and have had no occasion to regret it.

The technic of cleansing compound fracture wounds in which there was no protruding fragment, and of all other types of wounds, differed only in respect to one important detail. This, the initial step, consisted of closing the wound temporarily with Michel clips to prevent soiling it while the skin was being prepared. This not only prevented the dirty wash water from running into the wound but also permitted scrubbing across the approximated skin edges. After the skin had been rendered surgically clean the clips were removed and the wound opened widely, irrigated and débrided. If the laceration of the skin was too small to permit adequate exposure for purposes of inspection, débridement and irrigation, it was enlarged. Regardless of the degree of soiling, severed tendons and nerves in wounds treated within eight hours after the time of injury were sutured immediately. This can be done with little risk of infection if the wound has been properly prepared by copious irrigations and thorough débridement and by the topical application of sulfanilamide.

Tetanus antitoxin was administered routinely. Clostridium welchii perfringens antitoxin was not used. Routinely, we gave all wounds immediately a course of *x*-ray therapy upon the assumption that these rays are as effective in preventing infection from Clostridium welchii and other gas forming anaerobes as they are in the treatment of established infections.

All wounds of the extremities were immobilized either in traction or by splinting or casting. If a cast had been applied, a small window was immediately made to expose the wound for purposes of frequent direct inspection and palpation. The plaster casts in most instances were nonpadded.

All patients with major wounds were hospitalized for at least forty-eight hours. During this period they were kept at complete bed rest with the injured part, if an extremity, elevated above heart level. This period of hospitalization was insisted upon to assure constant observation by trained observers. During this period a minimal fluid intake of 2,500 cc. was maintained by mouth or parenterally when the oral route was not available or adequate. Blood was given until relatively normal levels of hemoglobin and red cells had been attained. Vitamin B-complex and C were given in therapeutic doses routinely.

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DISCUSSIONS OF PAPERS OF DR. WEIL AND DR. BISGARD

PHILIP D. WILSON (New York City): I want to say that I think both of these presentations of Dr. Weil and Dr. Bisgard are very thorough presentations of quite profound studies, and I am sure that they must be convincing to all of us that chemotherapy, both locally and generally, represents a real advance in the treatment of contaminated and infected wounds.

We are all thinking today in terms of military surgery and what can be done to prevent serious infections in the military cases that are being produced abroad and may soon be produced in our own forces.

There are certain points that I think ought to be made in relation to the treatment of air raid casualties. In the first place, they tend to have multiple wounds. These multiple wounds involve perhaps as many as a hundred or more small penetrations of the skin.

Most of these are minor, but no one can tell where one of these things may strike a vulnerable structure like an artery or a nerve and cause serious damage, so that every one of them has got to be inspected very carefully in order to be sure not to overlook some serious injury.

In the second place, most of these patients show shock. We know that the blast of high explosives can produce death even without visible wounds. Many corpses are found after air raid attacks on which there have been no marks at all of external wounds, and all of these people who have sustained wounds have been exposed to the effect of the blast. If blast can kill, it can also produce shock, and all of these patients are shocked. It tends to make the surgeon very wary in his approach as to what he is going to do, and so the surgical approach to the treatment of these patients is definitely conditioned by these two factors.

There is also a third factor, and one which is not given enough attention, namely, the condition under which the operative treatment is carried out. During an air raid attack, you may be without light, water, electricity or heat, and consequently the treatment of many of these patients has to be postponed until better conditions can be obtained.

Again, there is the factor of oppressive work. A great many cases accumulate in one hospital, and the surgeon is laboring under great pressure. In addition, is the fact that the operating rooms in many of the hospitals have been improvised in the subterranean vaults of the hospital for greater safety. Their trained crews have been taken away, and they have a team that is not as thoroughly trained as it might otherwise be.

Now, we all know that even under civil conditions there are operating rooms which for one reason or another are not such that they present ideal conditions for an aseptic operation, and this is certainly true under war conditions, and this definitely influences what you can attempt to do in the early treatment of these patients.

One must arrange one's operation, carry out one's treatment with a view to dealing with later infection, and this is particularly true because there is such variation in the types of the wound. You may have a small wound produced by a small missile, causing the butterfly type of fracture and not making an exit. On the other hand, you may have a fragment of shell casing entering through a small wound, producing comminuted fracture of the bone, and then imparting motion to those fragments so that they are thrown out; then you have a huge wound of exit and a very badly shattered comminuted fracture.

Another thing, we believe in the operation of surgical cleansing carried out, I think, in Dr. Bisgard's technic. As he describes it, it would be ideal if it could be carried out and one had the time to do it. One ought to aim at least to do it.

Following that, we should use chemotherapy in the wound, and while sulfanilamide is probably the least irritating of the drugs, I personally prefer sulfanthiazol, because of its greater activity against various strains of organisms, and particularly against the gas-producing organism.

There has been a good deal of work done showing that sulfanilamide has practically no effect against Bacillus welchii while sulfathiazol does have a very definite effect.

The splinting of these fractures represents a problem, and we believe in the closed treatment of these wounds and in dressing them and not disturbing them for as long a period as possible. If a thorough surgical cleansing operation can be performed in the first instance, and if then this wound can be shut up, even if it is allowed to granulate, it seems to me that we can expect the best type of healing.

I said that the closed plaster treatment was being carried out in England extensively. I mean by that, the Orr-Trueta method of treatment; and if the wound is properly treated in the first place, infection can be largely prevented. The wound is packed with gauze and then sealed over and treated in plaster, and is not disturbed again until there is some definite indication for doing so, either in the way of toxic reaction, fever or complaint of local pain.

Local pain is one of the greatest guides, I think, in controlling the progress of the case. These patients should be comfortable, and if they complain of pain it always means that there is something going wrong locally and demands investigation. I think the Orr-Trueta method of treatment is being used universally.

ROBERT I. HARRIS (Toronto, Ontario): We might with profit ask Dr. Bisgard and Dr. Wilson to comment on what seems to me to be a most important and critical aspect of the treatment of compound fractures, as demonstrated by the presentations before us today.

Dr. Bisgard has shown us excellent results and beautiful technic in the treatment of compound fractures in civil life, in which he has treated

the wound by primary closure, a method which I think has a great deal to recommend it in civil life.

Dr. Wilson, dealing with war wounds, is going to show us a film dealing with the treatment by the Orr-Trueta method in which the wound is packed open and heals.

I think this presentation would be incomplete unless we discuss the merits of the treatment, aiming at primary closure and primary wound healing as against a method in which healing by granulation is striven for. In what cases may we hope for primary union? In what cases shall we close the wound? In what cases must we use vaseline pack?

PHILIP D. WILSON (New York City): This first case being shown is a compound fracture of the femur that had been treated by surgical cleansing. B.I.P. had been put in the wound and primary closure had been done. This patient reached us some four days after injury with his fracture in a very bad alignment, and we treated this patient by insertion of the Anderson apparatus to get and maintain alignment.

The incision is closed and covered with a dressing. This case went on apparently quite well in plaster. At the end of four weeks, the plaster was changed, and at this time it was found that the wound had broken open, was suppurating and discharging very foul material. After that it had to be treated, of course, with the wound packed open.

We finally got union, but he still has a sinus some six months after operation. I think the result in this case would have been distinctly better if he had been left open in the first place and the wound allowed to heal by first intention.

The Anderson apparatus gave us an ideal method, particularly in the case of a femur, of attaining reduction and maintaining alignment, together with complete fixation. In these badly comminuted fractures, it is quite impossible to use internal fixation. You would have to use or depend upon distraction, assuming there are so many fragments that it would be impossible really to put them all in alignment. Certainly in the treatment of the wound I believe that complete immobilization is of tremendous importance in promoting the local, definite reaction and preventing infection.

Therefore, we put in pins and then incorporated the whole thing in plaster. In other cases in which we could do so, we put on a side bar locking these pins in place, and then applied our plaster over the whole apparatus. That had the advantage that when we went back to do a second dressing, our alignment was maintained when the plaster was removed, and we did not have to line the fracture up all over again.

In this case I had a pin through the tibia. When he came to us we left it in place but put a Kirschner wire through the lower end of the femur and a double Anderson pin in the upper fragment. This case did not require immobilization of the hip, as the other fragment was adequately controlled by the upper pin.

These patients can frequently be allowed to get up at the end of three or four weeks. We do not allow weight bearing, but it is a great help to morale if they can be ambulatory. We do not insist upon it, but it is purely a question of whether the patient feels well enough to do so.

Another of our patients was a bombardment casualty who suffered a compound fracture. He came to us four days after injury. This man's wound was tremendous. There was extensive comminution of his femur. When he first arrived he was already infected. His wound was full of Bacillus welchii and mixed flora. We washed out the wound, made sure of a thorough drainage, packed the wound with sulfathiazol, reduced it by the Anderson apparatus which maintained complete fixation even though the plaster had been removed. The wound was packed with gauze and wrapped in plaster. He has made very considerable progress.

I think that the best method of applying sulfathiozol is with an insufflator, but we had difficulty in getting them and we had to use the best method we could. We used our sulfathiazol. It was prepared in sterile powder, and we had it in doses varying from 2 to 7 Gm.

At the next dressing four weeks later, our pin units still held and the patient had very good alignment of his fracture. He will have full length. As a matter of fact, I have just had a follow-up on this case from Dr. Cole, saying that they have taken out the pins at the end of five months, that there is local infection about the pins but nothing at all serious. The patient will probably discharge a small ring sequestrum. His wound is now represented by a small draining sinus, and he now has union.

You see there has been very considerable progress in the healing of this wound. We were afraid to use these pins in such close approximation to an infected wound, and particularly closing it up with plaster, where inevitably these pins are going to be bathed in pus.

We gave the patient sulfathiazol orally as well as locally, and I think this tided him through the period in which the invasive type of infection might take place.

In twenty-eight cases that I now have notes on of compound fractures in which pins were used, we had no serious infection and no case in which the pin had to be removed.

The fixation in this case is so complete that we can apply a short plaster now and permit knee flexion, but the plaster is a means of sealing off the wound, preventing any gross contamination.

G. Gavin Miller (Montreal, Quebec): There is little to add in discussion of these excellent papers and Dr. Wilson's exhaustive discussion.

In handling recent sounds one factor needs emphasis: This is the necessity of thorough cleansing and débridement of wounds in order to get healing by first intention. All wounds treated in this way within six hours of onset should heal without infection. I find it difficult to persuade the house staff to do this with sufficient thoroughness so that freedom from infection is assured.

With dependence on sulfathiazol to prevent infection, even greater laxity may be expected in wound cleansing which is to be deprecated. In my opinion, the most important procedure in early wound handling is thorough cleansing.

I do not think it necessary to leave a wound open if inflicted less than six to eight hours before treatment is instituted, as a very large percentage of these will heal by first intention if cleansing is adequate.

If a wound has been inflicted eight or nine hours, or more, before being seen by the surgeon, the wound should be left open and packed. There is no time to say more but I would like again to express my appreciation of these excellent papers.

HENRY C. MARBLE (Boston, Mass.): I am very much interested in these papers. They present two sides. I am very much interested in chemotherapy. We saw the word "contaminated"; we saw the word "infected." In all infection, I want to know how they knew they were contaminated. With all respect, I want to know how they knew they were infected. We have no control.

I have made it a rule that any wound which is cleaned up and in which one of the sulfa derivatives is put in, first that the material removed shall be put in an aerobic and an anaerobic culture. Then, when we are talking about wounds sterilized by these chemicals, we shall know whether or not they ever were infected.

I would like to ask Dr. Bisgard in all sincerity if he will put in his moving picture a couple of broth cultures, putting that contaminated material as it is removed into a broth culture. Then show us the Bacillus aerogenes capsulatus growing. In that way we will know with what we are dealing.

I think we shall make it an absolute rule in all these cases that before we report the results, we know whether or not the wound was primarily infected with organisms that were going to cause trouble.

GROVER C. WEIL (closing): In reference to Dr. Marble's questions relative to the period of contamination and preliminary wound cultures, we believe they are essential factors in the consideration of prophylaxis, infection and wound healing. Preliminary cultures have been taken of all wounds at the time of inspection. The quantitative recovery of the primary contaminators as a rule were low, the variety many and undoubtedly at this point low in virulence and invasive properties. If the environmental state of the wound is favorable for certain of the contaminating organisms, the period of contamination becomes shortened and infection develops. We have arbitrarily set the period of contamination at four to six hours.

Our results to date in the prophylactic and local use of sulfathiazol have been most impressive and encouraging. The use of the drug in the prophylaxis and treatment of surgical infections should, by no means, interfere with the modern principles of standard surgical technic in the care of injured tissue such as débridement, etc.

J. Dewey Bisgard (closing): Dr. Harris brought out the difficulties of using this type of technic for the type of wound occurring in military practice during war. I agree that there would be some difficulty in providing the very large quantities of sterile salt solution but I think it is not unsurmountable. It could be transported and supplied in tanker trucks or nonbreakable containers. However, the time element is a real obstacle and would probably prohibit the very wide use of copious irrigations at the front. It requires usually a couple of hours to clean a large wound and handle it in the way demonstrated.

More recently I have used a combination of both sulfathiazol and sulfanilamide; I mean, using both drugs in the wounds. However, Keyes, of St. Louis, has shown that sulfanilamide is more effective than the other sulfonamides in preventing infection in contaminated wounds in animals.

In reply to Dr. Marble's remark, I restate that in twenty of the twenty-five cases there was evidence that foreign bodies had entered the wounds, or that the bone fragments had been exteriorized. It is inconceivable to me that a fragment could protrude through the flesh and clothing, with dirt all about, without being contaminated.

In eighteen out of the twenty-five cases cultures were taken from the wound at the time of débridement and positive cultures were obtained in fourteen.

# TRAUMATIC ABDOMINAL SURGICAL EMERGENCIES

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TRAUMA of the abdomen constitutes an important group of injuries not only producing disability but also ending far too often in sudden death. Much of this is due either to entire lack or to slow application of proper emergency treatment. Far too often a patient arrives at the hospital with an abdominal trauma, having received no emergency care at the site of the accident. Irreparable damage is likewise done through improper handling by well meaning but inexperienced persons. Many times the injured person is placed in the first available automobile; he is rushed over roads and streets at a high rate of speed, thereby damaging the traumatized abdomen still more and increasing the shock with every jolt and turn.

The medical profession must realize the importance of prompt and proper first aid treatment for patients with abdominal trauma. Naturally physicians must be thoroughly trained in the fundamentals of first aid and in appreciating the importance of first aid for this class of patients. Every member of this organization needs to go forth and preach the gospel of first aid to physicians so they can direct the laity and can actively promote better emergency care to cases of abdominal traumas. Such first-aid service is possible through the training of those who are brought in contact with accident cases. This is especially important in modern warfare as abdominal trauma is exceedingly common in military activity.

It is also necessary for interns to know the principle of first aid for abdominal trauma while serving on the ambulance or in the emergency room at the hospital. The general practitioner likewise renders emergency treatment to cases of abdominal trauma. He should be prepared to handle those he is capable of treating, but he should not fail to recognize early those he is not equipped to treat. The physician who accepts a case of abdominal trauma for treatment beyond the emergency is responsible for the end results, not the surgeon who sees the case when failure is imminent. Likewise a surgeon who assumes the responsibility of treating these patients must be willing to accept

many patients for exploration. He must be willing to give them much of his time, making painstaking examinations, performing extensive technical operations, giving that close postoperative attention which in itself will do much in reducing the mortality rate.

"Treat them where they lie" is truly the first principle in the emergency treatment of abdominal traumas as well as of fractures. This treatment should begin immediately at the scene of the injury and should first combat shock, then check hemorrhage and relieve pain. If shock is profound, no movement whatsoever should be allowed until improvement has occurred. Many lives have been sacrificed through subjecting patients in shock from abdominal traumas to the added traumas of transportation.

Abdominal trauma may be parietal, visceral or parietovisceral; it may be closed or open. Any abdominal trauma calls for immediate close attention; therefore, the patient should be carefully examined to determine the diagnosis. In many cases a history, carefully taken and recorded, and a physical examination are sufficient for a correct diagnosis. Others require laboratory examinations before a diagnosis can be determined.

The trauma may be limited to the abdominal wall, but one must be certain of this fact. With a closed trauma of the parietes the pain and tenderness are usually localized to the site of the trauma. Among the closed traumas are ruptures of the rectus muscle and deep epigastric vessels. The commonest site is below the umbilicus. Profuse hemorrhage follows rupture of the deep epigastric vessels; it is frequently difficult to differentiate between hematoma of the abdominal wall, intraperitoneal, and retroperitoneal hematoma. However, with the first the swelling in the abdominal wall protrudes prominently if the patient blows with the nose held tightly, while an intraperitoneal or retroperitoneal mass will disappear. If the intraparietal hematoma is large and increasing in size, it must be evacuated; bleeding vessels must be clamped and ligated; any rupture of the muscle should be carefully sutured. There may be a great deal of damage to the parietes with the loss of much tissue. One should consider every incised, lacerated, or puncture abdominal wound as potentially penetrating, until it is proved otherwise.

Most open wounds of the abdominal parietes, regardless of how dirty they are, if seen early, i.e., within four to six hours, can be cleansed and prepared so that primary union occurs. Nevertheless, despite meticulous cleansing there are some wounds so heavily contaminated that infection occurs. Furthermore, there are some

virulent types of contamination which the body defenses seem impotent to combat. The abdominal wall should be shaved, then scrubbed with green soap and warm water until it is quite clean. The

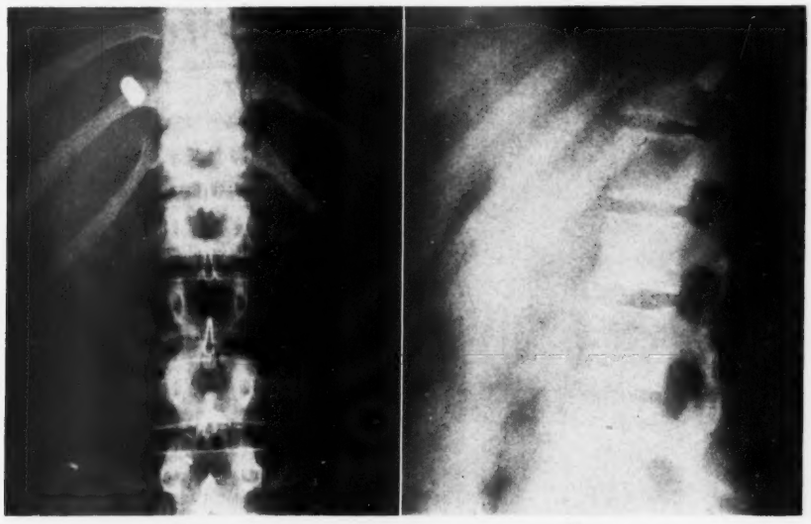

FIG. 1. FIG. 2.

FIG. 1. Anteroposterior view of abdomen showing bullet entering abdominal wall through left side, perforating the left lobe of of the liver, diaphragm, pleura, lung, again the pleura, and a compressed fracture of the body of the vertebra with compression of the cord.

FIG. 2. Lateral view of location of bullet in relation to the spine.

skin surface thereafter should be rinsed thoroughly with sterile water, dried, and washed with ether. All foreign material visible in the wound must be removed; tissues which are obviously devitalized must be excised. Irrigate the wound thoroughly with normal saline solution, forcing this into all crevices of the wound. A chemical bacteriocide can be applied to the normal skin of the abdominal wall. One should cautiously explore the depth of the wound to make certain that it is limited to the parietes or that it enters the abdominal cavity. There must, of course, be complete control of hemorrhage. This should be followed by the placing of from 5 to 10 Gm. of sterile crystalline sulfanilamide in the depth of the wound. Wound closure with the least number of annealed steel wire, cotton, or silk sutures, without tension, will usually result in primary wound healing. Wounds too extensive for satisfactory approximation of the edges, can have a plastic repair if the patient's condition permits; otherwise, pack with vaseline gauze and protect with dressings or pack open and irrigate with Dakin's solution every two hours. Plastic repair can be done when the patient's condition warrants it. Naturally, one would

give antitetanic serum after testing for sensitivity. The patient should be closely observed and given such treatment as indicated.

Notwithstanding the improved preoperative preparation and the

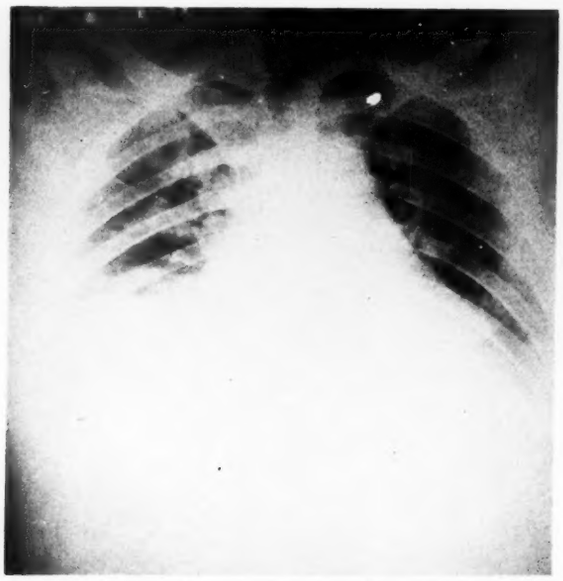

FIG. 3. Ruptured viscus (stomach) in supine posture, showing only elevated diaphragm on right.

postoperative treatment of today, perforating abdominal wounds have approximately the same mortality as twenty-five years ago. The mortality rate increases in proportion to the age of the patient and the size of the missile. Incised, stab, or gunshot wounds may enter the peritoneal cavity, yet cause no damage to the viscera; however, they may, and probably will, introduce contamination resulting in a fatal peritonitis. The majority of persons with penetrating abdominal wounds die within twenty-four hours from hemorrhage and shock. Those dying after this time succumb to peritonitis. Many incised and stab wounds appear to be limited to the parietes; yet as has been suggested, these must be considered potentially penetrating until proved otherwise.

There are no reliable symptoms sufficiently constant to indicate the absence or presence of visceral traumas. With the presence of general muscle rigidity and tenderness, pain and pallor, one can be fairly certain of an intra-abdominal trauma. Even in the absence of clinical symptoms of an intra-abdominal trauma, indication for surgical intervention is always present. Patients arriving at the hospital in a serious state of shock should be treated for this condi-

tion before an examination is made. If after three or four hours the pulse rate continues rapid with a falling blood pressure and a reduction in the hemoglobin and red cells, or if air hunger develops, one

FIG. 4. Same as Figure 1, in upright posture showing free air or gas under diaphragm.

can be certain that hemorrhage exists. Therefore, an early operation is imperative, provided there is any reasonable prospect of the patient surviving the operation. Patients apparently in suitable condition should be sent to the operating room for examination. As you know, many patients require very close study to determine the advisability of operation. The surgeon naturally will use every means at his command to aid him in reaching a conclusion. The best surgical authority available should be called into consultation. Roentgenograms should show the presence of free air or fluid in the abdominal cavity. The peritoneoscope will also be a valuable aid in determining if there has been a penetration with blood or intestinal contents extravasated into the peritoneal cavity. With every facility available to meet emergencies, enlarge and explore the wound to its depths. If the incised or puncture wound has entered the abdominal cavity, an exploratory laparotomy must be performed as every perforating

wound of the abdomen means a probable perforating wound of the gastrointestinal tract or some other viscus. Eviscerated omentum should be resected before the abdomen is opened or explored.

FIG. 5. Intra-abdominal trauma with pelvic fracture and rupture of bladder shown by extravasation of fluid in cystogram.

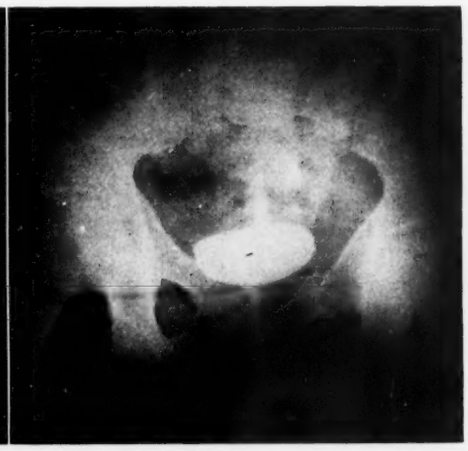

FIG. 6. Same as Figure 5, after healing of bladder defect following open surgical repair.

Eviscerated intestines should be cleansed by irrigating with warm normal saline solution and flushed with ether. Perforations should be closed before the intestines are returned to the abdomen.

Gunshot wounds of the abdomen frequently produce profuse hemorrhage and profound shock. Most of the fatal cases succumb within a few hours. They are so quickly fatal that no type of treatment offers hopes of benefit. Even apparently hopeless cases, however, should be given every chance for recovery. The immediate intravenous administration of acacia, plasma or serum and normal saline solution may prove a lifesaver. Patients in shock must be treated for this condition and observed frequently. When the patient fails to recover from shock in three or four hours, it is reasonable to suspect that the condition is due to actual blood loss; therefore, prepare the patient for exploration as soon as the blood pressure has been raised to a level at which a laparotomy can be fairly safely performed. Patients arriving at the hospital without much evidence of shock should be taken to the operating room immediately for examination and preoperative preparation. A careful history should be taken and recorded. The physical examination must be thorough and the findings recorded. The bullet's wound of entrance and exit is particularly important; an imaginary line connecting these two

wounds will indicate the course of the bullet through the body and the probable resulting trauma. If the bullet is still in the body, a flat *x*-ray film should be made and quickly developed to provide informa-

FIG. 7. Extracapsular rupture of left kidney; pyelogram showing diffused material in kidney area and loss of kidney outline.

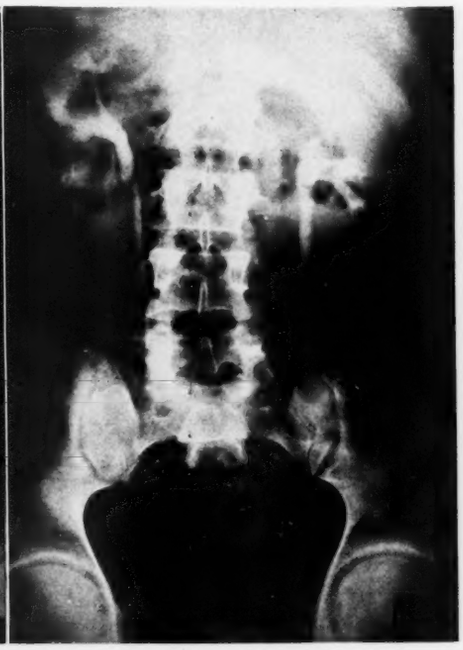

FIG. 8. Rupture of the right kidney; pyelogram showing intracapsular extravasation of diotrast about kidney pelvis.

tion regarding the location and size of the missile. It is often difficult to determine the optomal time for operation; yet the most important element aiding the recovery of patients with bullet wounds of the abdomen is a short interval between the injury and the operation. The decision whether to operate immediately or not is usually based on the rate and character of the pulse and the blood pressure reading. Patients showing a reduction in the pulse rate with an increase in its volume and a satisfactory blood pressure rise are probably good risks for operation. One with a feeble pulse of 120 or over and a blood pressure of 90 mm. or under is in a grave condition and could hardly be expected to survive an operation; therefore, every effort should be made to improve the patient's condition before an exploration is undertaken.

Regardless of the location of an incised or punctured wound through the abdominal wall, intra-abdominal exploration requires a long midline or a paramedian incision. As soon as the abdomen is

opened, blood clots and semisolid fecal material should be removed with the hands; then the cleansing process may be continued with suction until finally a complete toilet of the abdomen and its contents may be made with sponges wrung out of warm normal saline solution. Next check all hemorrhage by seeking out the bleeding vessels and ligating individually, avoiding mass ligation and devitalization of tissue. Thereafter systematically examine for trauma to the viscus. This may reveal many injuries.

Percutaneous abdominal traumas usually result from direct force applied to the abdominal wall; they rarely occur from indirect force due to muscle effort. Trauma caused by blunt violence are of two types; the widespread traumas caused by a severe crush, and the limited lesion following a sudden local trauma. Crushing injuries are usually multiple, often producing death within a short time. The limited trauma is the most dangerous. Frequently there are no external signs of trauma and symptoms of visceral trauma may be absent soon after the accident. Circumscribed blows more commonly injure the stomach and intestine when distended, also the bladder; on the other hand, diffuse force is apt to result in trauma to the more fixed and solid organs, such as the retroperitoneal colon and duodenum and the liver and spleen. Percutaneous injuries produce many types of traumas. Among these are, contusion and rupture of the free large and small intestine, retroperitoneal rupture of the colon and duodenum, tearing of the mesentery from the intestine, tearing of the mesenteric vessels, tearing of the omentum, trauma of the mesenteric, omental, and splenic vessels with resulting infarcts, rupture of the liver and spleen, together with an associated rupture of the bladder, kidney, and diaphragm, postperitoneal hemorrhage or a combination of any of these. These injuries are frequently fatal because their seriousness is not recognized early; accordingly, emergency treatment is neglected, hospitalization is late and since diagnosis is frequently difficult, appropriate treatment is delayed. Patients arriving at the hospital after an accident, apparently in good condition, should be carefully examined for trauma. Even with lack of symptoms and no evidence of a trauma, they should be put to bed and observed frequently. Blood pressure readings and pulse rate should be taken every half hour. Often in the presence of a ruptured viscus, definite symptoms may develop slowly. The presence of an acute abdominal pain, of muscle ribidity, and tenderness with an anxious expression, of pallor, of an increasing pulse rate and a falling blood pressure should make one suspicious of a serious abdominal

trauma. Therefore, a careful examination should be made to determine the cause of the patient's condition. In many cases a carefully taken and recorded history and a painstaking physical examination are sufficient for the diagnosis. Though under some conditions a definite diagnosis can not be made, time spent in attempting such a diagnosis, and in preparing the patient for an operative procedure, will still reward one for the effort, for this time will give a decreased morbidity and a lower mortality.

Associated traumas to the bladder, kidney and diaphragm are common in both penetrating and percutaneous intra-abdominal traumas, therefore, they should be looked for in all such cases.

Recent advances in surgery have taught us to be more careful in evaluating the patient's fitness for surgery. Preoperative preparation of the patient, pre-anesthetic sedation, and the postoperative care are frequently of more importance than the operation.

Contamination of the peritoneal cavity by penetrating wounds or percutaneous rupture of hollow viscus does not invariably require drainage; many cases do well without drainage. One should, however, make an effort to remove contaminating foreign material from the peritoneal cavity at the time of the operation. Patients frequently die of spreading peritonitis because absorbed toxins have not been adequately neutralized. The local and general immunity are the processes which actually protect. We have used Coli-Bactragen in a considerable number of perforated and ruptured wounds of the intestine, and we believe that the results obtained justify continuing the procedures. Also, the prophylactic use of sulfanilamide in these cases has apparently resulted in a marked reduction in the morbidity and mortality. Though it is true that peritonitis of traumatic origin is a polymicrobic infection and that sulfanilamide is not fully effective against all the bacteria present, still other conditions appear to be favorable for the therapeutic action of the drug.

A large number of patients surviving an operation performed within the first six hours after such traumas will recover if given close attention and proper postoperative treatment. Complete rest and good nursing are essential.

## CONCLUSIONS

The reduction of the high mortality due to traumas of the abdomen lies first and foremost in the dissemination of much of the information embodied in this paper. There is little here that has not previously been said. Many are as familiar with this subject as the

author; and yet at the same time there are many physicians engaged in general practice who have not had the opportunity to inform themselves on much herein outlined.

But equally, and perhaps of greater importance, is the need for instructing the laity in proper procedure when an accident occurs. It is indeed rare for a physician to be first at the scene of an accident; and in those first precious moments there are a few simple procedures the layman could do—or abstain from doing—that would expedite the surgeon's task enormously and would save many lives that are now needlessly being sacrificed.

### DISCUSSION

HENRY C. MARBLE (Boston, Mass.): I think at the moment there is little to add. Perforating wounds of the abdomen, as Dr. Palmer has pointed out, are important and require organization once they are in the hospital.

There is across the river from Boston a little hospital in an underprivileged community, in which we occasionally have cases of perforating wounds of the abdomen, often with stilettoes, sometimes with bullets. The rules for the junior staff in that hospital are that all perforated wounds of the abdomen shall be explored with no delay.

The advent of blood banks has made it possible to proceed boldly to the operation, and to rescue the patient from the shock or from the increasing shock with blood or blood plasma or saline.

Recently at a staff meeting, a young surgeon presented his case. He told about the patient having been impaled upon a stiletto, and as he presented his case he stated that the white count was 10,000. The only criticism of the presentation (he had a nice operation and repair to the wound) was that one gentleman inquired why they bothered with the white count.

Now, the other group of cases are, as we see them, mostly children. In Chelsea, apparently, it is the favorite diversion of the child in the street to throw himself under the passing automobile, and the history as they arrive in the hospital definitely states that the wheel of the automobile went right across the child's abdomen. That presents all of the picture.

Here, again, the only thing I can say is that the blood bank is of value. But as far as I am concerned, the junior surgeon or the resident in charge can cancel all appointments for the next twenty-four hours, and if he cancels all appointments and sets himself down beside the patient and does nothing else, I think mortality will be on the decrease. He, and he alone, is the only person equipped to evaluate the changing conditions, and the more closely he sticks to that patient the better able he is to evaluate the necessity for exploration or for operation.

D. C. PATTERSON (Bridgeport, Conn.): The subject assigned to Dr. Palmer is so big, that it is very difficult to cover it in a short time. I want to

compliment him on the field he has taken in. The treatment of these injuries, as he says, requires the best surgical skill, with all that implies, namely, preoperative study and preparation, meticulous and competent operative care and very conscientious after-treatment.

There is not a great deal that can be done at the scene of the accident. These patients, you might say, have automatically splinted the abdomen. They can be kept warm, shock can be reduced and morphine administered, but they should be gotten to the hospital as soon as possible.

The most important thing in the early stages is the careful observation and study of the patient himself, and it is well to bear in mind the truism of Gorrel, that "where one mistake is made by not knowing, ten mistakes are made by not looking."

The external wound on the patient may give little indication of the seriousness of the internal injury. We had one patient come in—a street sweeper—and the only accident that he could report was that in pulling his brush toward him he struck the handle of his brush against the lower left flank. He later complained of pain and was sent to the hospital. We found that he had a rupture of the sigmoid. Fortunately, he made a good recovery.

We had, two winters ago, as the result of coasting accidents, three cases on the service at one time; a ruptured kidney, a ruptured spleen and a ruptured liver. To put it briefly, we left the kidney alone, removed the spleen, and packed the liver, this was in a girl of nineteen, with a huge crack across the dome. They all made very good recoveries.

In the matter of kidney injuries, before one should ever think of removing the damaged kidney, he should be sure that the other kidney is properly functioning. I know of a case in which a damaged kidney was removed three or four days after an accident, so it hardly seems as if it were necessary, without the other kidney having been investigated. Unfortunately, the only kidney that he had was the one that was removed.

In injuries of the spleen, the matter of delayed hemorrhage has been brought to our attention. We had a patient that developed hemorrhage seven days after a baseball blow in the region of the spleen. Fortunately, he had remained in the hospital all the time. I think if we had been real smart, we would have known the state of the spleen and removed it before it ruptured.

There is one thing the doctor spoke of that I cannot quite agree with, that is, the drawing of the straight line between the wound of entrance and the wound of exit of the bullet. It has been our experience that the course of a bullet in the human body is about as erratic as a downhill putt; you never know what is going to happen after a bullet enters the body.

Just one thing further which I should like to mention. They have strange ways, probably, in Bridgeport, but we have had several cases of compressed air rupture of the intestine. Three of these I have had personal experience with, only one of which came to the hospital in time for operation. The

others were admitted in a moribund state. One of them was malicious, one was a joke and the other was purely accidental.

In regard to the way those things can happen, the men in the foundries had a habit, at the end of the day's work, of dusting each other off with a compressed air hose. It is not necessary for the nozzle to be inserted in the anal opening, or even in the buttocks; if it comes within six inches, the conformation of the buttocks produces a funnel through which air can enter the intestinal canal.

It is well to warn all safety men in factories against this very pernicious practice of dusting off the clothing with compressed air.

CHARLES JOHNSTON (Detroit, Mich.): Dr. Palmer has painted a rather bright and pretty picture of how to handle these surgical emergencies. In the case of a stab wound or gunshot wound, I think I can agree with him that we can outline fairly well what to do. The problem is not one, as Dr. Marble suggests, for a resident to watch; it is one for the entire staff. The more experienced person must be perfectly willing to get up in the middle of the night and wrestle with this problem. Too frequently, these patients are brought into the emergency room, a diagnosis is hoped to be obtained there, and a decision made on whether or not to operate. Usually these patients are much better off if taken to their beds and allowed to get some rest and then studied. During this interim, of course, blood transfusions should be given to combat hemorrhage or shock and any other problem which they present should be met.

The difficulty in diagnosis is extreme. Many of these patients may show very little in the beginning after very severe intraperitoneal trauma; others may show signs of tremendous shock and have nothing wrong with their viscera at all.

Two complicating features have caused us difficulty in diagnosis in the cases which have not had real trauma to the intra-abdominal structures but which simulated it. These are acute dilatation of the stomach, and rigidity of the abdomen associated with fractured ribs. Frequently, patients with minor trauma will have an acute dilatation of the stomach and will appear practically moribund when brought into the hospital. These will respond quite rapidly to relief of the distention. Chest injuries, especially fractured ribs, may cause enough rigidity to suspect that the patient has a fullblown peritonitis.

Dr. Charles Henry, of our staff, has carried out studies on perforations, especially ruptured ulcers in which the acid is allegedly high, and his data indicate little harm from chemical effects. The same things hold for the ileum also, i.e., that the chemical aspects of the peritonitis are of very minor importance. It is the bacteria that are present, and the fact that many individuals have not found bacteria means that the organisms have been so diffused by the inflow of fluid that a decent culture is not obtained.

Dr. Henry found that if he takes a large enough quantity of material, the bacteria will usually be found. Furthermore, he has found that the chemical composition of the intraperitoneal fluid after ruptured ulcers is practically that of blood serum. In other words, the ill effects of the chemical (the acid or the alkali) are pretty well neutralized. We have not studied enzymes, however, and it is possible that the enzyme may be a dangerous factor.

The greatest complications that we have seen are, of course, bleeding and peritonitis. Frequently we have seen, without other injury, mesenteric injury, i.e., bruise to the mesentery and subsequent thrombosis of the mesenteric vessels. It is practically impossible to diagnose the situation before death. The patient gets a marked ileus which is assumed to be the ileus based on trauma, which we of course see quite commonly in these cases and which, if intubated and allowed to right themselves, will recover. If marked vascular occlusion is present, death ensues.

I think this has been a very interesting subject. I want to point out that you cannot differentiate trauma to the abdomen from trauma generally, and attempts to farm out the care of these patients on an anatomical basis are absurd. Segregation of head injuries on the neurosurgical service, or chest cases on the chest service is not so good for the patient as it might seem. The patient must be looked at as a sick individual who has been traumatized, and must be cared for as a whole; he cannot be divided among various services. Someone has to take the responsibility for the patient.

# CORTICAL EXTRACT IN THE TREATMENT OF SHOCK*

## PRELIMINARY REPORT

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SINCE the work of Swingle and associates,[1] and others, on the possible rôle of cortical extract of the adrenal gland in the prevention and treatment of shock, much interest has naturally been developed in the problem. In general, there has not been any consistency in the opinions and results of experiments. A part of this inconsistency may, no doubt, be due to variations in dosage of the extract, and potency of the various agents used. Recently, synthetic products (corticostesterone and desoxycorticosterone) with cortin activity have been made available for use. Selye and associates[2] found that cortical extract was very effective in the prevention of shock in rats, but that desoxycorticosterone was not effective. These results have been confirmed by Weil and associates[3] who noted that when cortical extract and desoxycorticosterone acetate were given together, the mortality rate was reduced in rabbits subjected to manipulation of the intestine, but was not reduced following administration of the latter drug alone. Our experience is confined to the treatment of dogs subjected to shock producing factors such as hemorrhage or manipulation of the intestine, and to the treatment of patients subjected to major operations. Although our data are so meager as to be submitted chiefly as a preliminary report, the data on animals as well as humans suggest that cortical extract† does have a favorable effect in the treatment of shock, particularly from the prophylactic standpoint.

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† The cortical extract (eschatin) used in these experiments was kindly furnished by Parke, Davis and Company.

Adrenal cortical extract has been used in shock produced by numerous agents, including that caused by burns. Wilson and associates[4] found the extract to be effective in the treatment of burns, a finding corroborated by Lee and associates.[5] Whether or not the shock of burns is similar to surgical shock cannot be stated conclusively at the present time. Most investigators, including Blalock[6] and others, are of the opinion that the shocking effect of burns is due to a fluid and plasma loss at the surface of the burn and into the burned area (particularly during the first few days following injury), while a few investigators are of the opinion that toxemia plays a significant rôle. Administration of plasma in burns was first advocated by Elman and associates;[7] its efficiency is suggestive proof of the importance of loss of plasma in shock produced by burns, and offers evidence that the shock accompanying burns is similar to or identical with so-called traumatic shock.

Dogs were used in all experiments; ether anesthesia was used throughout. Blood pressure tracings were recorded on a drum by inserting a cannula into the femoral artery. The cortical extract was given intravenously or intramuscularly in doses varying from 0.5 cc. to 2.0 cc. per kilo of body weight. Shock was produced by two methods: (1) hemorrhage, and (2) manipulation of the intestine by squeezing a handful of intestinal loops every two seconds. Although the latter method might be considered somewhat crude, numerous investigators have found it very effective in producing shock, i.e., in causing a drop in blood pressure from 110 to 140 down to 70 or 80 in thirty to fifty minutes. We discovered that one of the most important factors in the consistency of time required for production of shock was the size of the animal. Since the hand squeezing the intestines is the same, the size of the dogs used for controls and active experiments must be relatively the same. We noted uniformly that it required much longer to produce shock by this method in large dogs. When hemorrhage was induced, the rate was always adjusted to 0.5 per cent of body weight every five minutes. The specific gravity of the blood was determined by the falling drop method as utilized by Barbour and Hamilton,[8] Scudder[9] and others.

*Series I: Shock Produced by Hemorrhage Alone.* As previously stated, in all experiments bleeding was instituted uniformly at the rate of 0.5 per cent of body weight every five minutes. Only four animals were used in this series, because data in other experiments (Series II and III, and Table 1) relative to the effect of cortin on the tolerance to hemorrhage in shock produced by manipulation of the

intestine were also available. Of the four animals used, hemorrhage alone was induced in two, hemorrhage after a prophylactic dose of cortin in one, and hemorrhage after and during administration of physiologic saline in a fourth. The survival time in these animals was thirty-nine, forty-six and sixty-five minutes, respectively. This datum is too meager to warrant conclusions, but when supported by additional data on hemorrhage as discussed later, leads us to the conclusion that cortin increases slightly the tolerance to hemorrhage, that fluids may be slightly more effective, and that cortin plus electrolytes and 5 per cent glucose are still more effective in increasing tolerance to hemorrhage

*Series II: Effect of Cortical Extract (Prophylactic Dose) on Maintenance of Blood Pressure Level during Manipulation Massage of the Intestine.* As stated previously, manipulation of the intestine with the hand at stated intervals (every two seconds) is a fairly effective and consistent way of producing shock in dogs. Blood pressure readings during manipulation of the intestine (without cortical extract) are available on five dogs. As shown in Table 1, the average drop in blood pressure after forty minutes of manipulation in animals not

TABLE 1

EFFECT OF CORTICAL EXTRACT ON THE BLOOD PRESSURE FOLLOWING MASSAGE OF INTESTINE AND ON THE SURVIVAL TIME FOLLOWING HEMORRHAGE AT A UNIFORM RATE (0.5 PER CENT OF BODY WEIGHT EVERY FIVE MINUTES) BEGUN NINETY MINUTES AFTER INTESTINAL MASSAGE WAS STARTED

| | Drop in Blood Pressure after 40 Min., Mm. | Drop in Blood Pressure after 55 Min., Mm. | Survival Time Following Hemorrhage Begun after 90 Min. Intestinal Massage, Min. |
|---|---|---|---|
| Without cortical extract | 35.3 | 38.4 | 21 |
| With cortical extract | 19.5 | 20.0 | 36.5 |
| Fluids (buf. gluc.) without cortical extract | 34.0 | 37.5 | 27.5 |
| Fluids (buf. gluc.) with cortical extract | 0 | 7.5 | 36.5 |

Note that there was distinctly less fall in blood pressure when cortical extract was used. Fluids (buffered 5 per cent glucose) alone had very little beneficial effect but fluids with cortical extract prevented shock, although the survival time following hemorrhage was no longer than when cortical extract was given without fluids.

receiving cortical extract, was 35.3 mm., and after fifty-five minutes of manipulation was 38.4 mm. On the other hand, in the animals (3) receiving a prophylactic dose of cortical extract (1 to 1.5 cc. per kilo

of body weight in divided doses eighty and twenty minutes before massage of intestine was begun), the average drop in blood pressure was only 19.5 mm. in forty minutes and 20.0 mm. in fifty-five

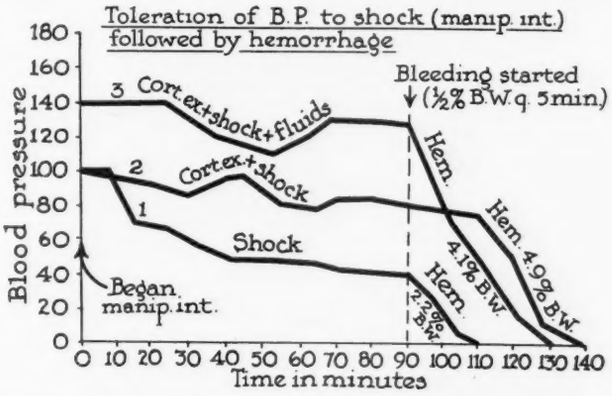


FIG. 1. Curve 1 illustrates the average fall in blood pressure in animals (dogs) submitted to intestinal massage. Note that administration of cortical extract (curve 2), and cortical extract with glucose and electrolytes (curve 3) lessen the degree of fall in blood pressure. When such animals are submitted to bleeding at the end of ninety minutes of intestinal massage, those without cortical extract are killed by much less bleeding, namely, 2.2 per cent of body weight contrasted to 4.1 and 4.9 per cent.

minutes. In this series of animals, bleeding (0.5 per cent of body weight every five minutes) was instituted ninety minutes after massage of intestine was begun. Naturally, the animals that were in shock because of the intestinal massage would not tolerate as much hemorrhage as normal animals. When cortical extract was given prophylactically, before the massage of intestine was begun, bleeding (instituted ninety minutes after the manipulation of intestine was begun) was tolerated much better, there being a survival time of thirty-six and five-tenths minutes to hemorrhage, contrasted to only twenty-one minutes in animals not receiving the extract.

*Series III: Effect of Fluids in Prevention of Shock (with and without Cortical Extract).* In a pair of animals receiving glucose (50 to 80 cc. per kilo of body weight, buffered with Hartmann's solution), but no cortical extract, manipulation of the intestine produced a drop in blood pressure of 34.0 mm. in forty minutes and 37.5 mm. in fifty-five minutes. (Table 1.) In another pair of animals receiving glucose and electrolytes, but to which cortical extract (1 cc. per kilo of body weight in divided doses about ninety and twenty minutes before manipulation of intestine) had been given, the fall in blood

pressure at forty minutes was 0 and only 7.5 mm. at fifty-five minutes. In other words, shock was almost completely prevented by the fluids and cortical extract, a result indicating even a more

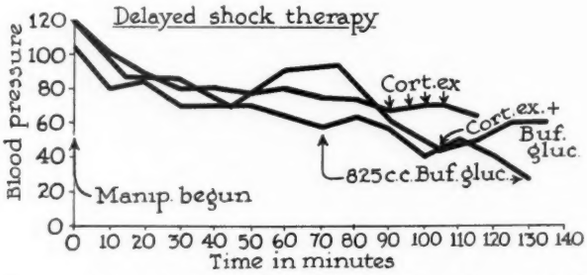


FIG. 2. After shock has been produced neither cortical extract nor glucose and electrolytes will elevate the blood pressure to a significant degree.

beneficial action than obtained with cortical extract alone. The survival time following hemorrhage, begun ninety minutes after institution of intestinal massage in animals given extract and fluids, was only thirty-six and five-tenths minutes, which is identical to that in animals given cortical extract and no fluids. After consideration of this and previous data, it appears that cortical extract is more beneficial in shock (produced by manipulation of intestines) than in hemorrhage.

No experiments were performed with the addition of plasma in the therapy of animals, since it is so well known that plasma is a very effective agent in combating shock. Harkins[10] has splendidly summarized all of the important data on the various features of shock in a recent publication.

*Series IV: Effect of Cortical Extract When Given after Shock Is Produced.* Shock was produced in a pair of animals by manipulation of the intestines; after the blood pressure had fallen to 60 and 67 mm., respectively, 5 per cent glucose buffered with Hartmann's solution along with cortical extract (up to 2 cc. per kilo of body weight) was given. There was no significant rise in blood pressure following administration of cortical extract (Fig. 2); in other dogs, administration of glucose and electrolytes alone likewise seemed to have no beneficial effect in correcting the shock. These findings support the belief that administration of glucose and electrolytes (particularly glucose alone) in the absence of plasma, as expressed by Blalock[11] and many others, may "wash out" plasma and electrolytes from the blood stream.

*Specific Gravity of Blood during Hemorrhage and Shock.* Conforming to the experience of Scudder[9] and others, we found that hemorrhage produced a decrease in specific gravity of the blood (as

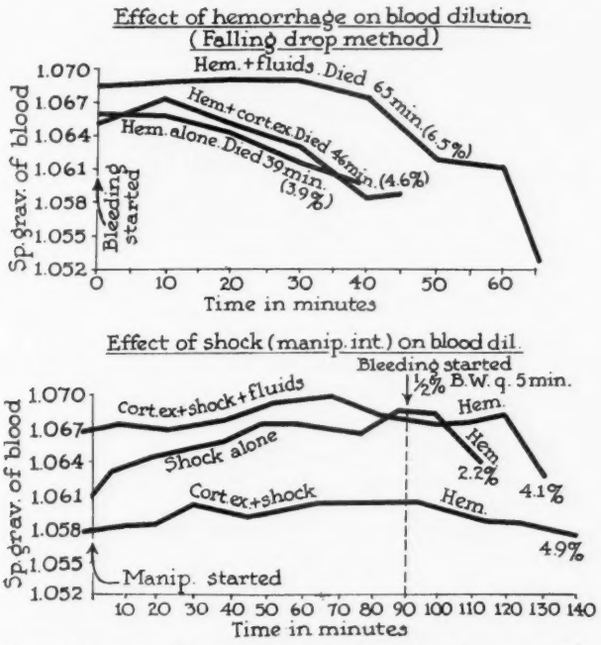


FIG. 3. The specific gravity of the blood, as determined by the falling drop method, decreases during hemorrhage (top graph), and increases during shock (lower graph). Note that the increase during shock (produced by intestinal massage) is slightly less when cortical extract is given to the animals an hour or two before the experiment is started.

determined by the falling drop method) and that shock produced an increase in specific gravity. (Fig. 3.) If hemorrhage is added to shock (in the late stages as noted in Figure 3), a sharp decrease in specific gravity is noted. When cortical extract is given as shock is being produced, there is a definite but slight tendency to maintain the specific gravity at a constant level, revealing little or no increase in specific gravity.

*Effect of Cortical Extract on Shock in Human Beings.* In an effort to determine the efficacy of cortical extract in the treatment of shock in a human being two methods of therapy were utilized: (1) patients representing isolated cases of shock (which fortunately in modern days are relatively rare) were treated with intramuscular and intravenous administration of cortical extract in doses up to 20 cc. per patient; and (2) extract was given an hour or two before opera-

tion, attempting to decrease shock manifestations. Although it happens that a very rapid recovery was obtained on every occasion in which the extract was used after shock was present, this fact does

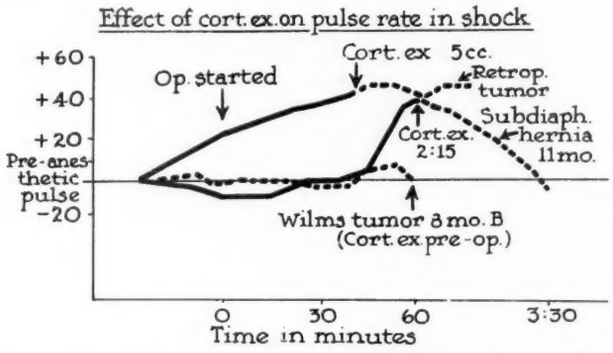


FIG. 4. The three curves represent the pulse rate in an adult during resection of a retroperitoneal tumor; in an eight-month's old infant, during nephrectomy for a large Wilms' tumor; and in a child submitted to repair of a subdiaphragmatic hernia (right side) in which a lot of manipulation, or retraction of the liver was necessary during repair. The adult having resection of the retroperitoneal tumor did not receive cortical extract until early signs of shock (rise of 40 in pulse rate) were present. The child having repair of the hernia showed moderate shock (pulse 180) developing during the last few minutes of the operation, but within eight-five minutes after cortical extract was given the pulse rate had receded to normal. As stated in the text, isolated cases of this type cannot be used as very significant evidence because we have no knowledge of the possible reaction without cortical extract.

not prove the efficacy of the drug, since we have no way of disproving the possibility that recovery would have been just as rapid without the cortical extract. Figure 4 illustrates three cases which revealed what might be considered a favorable effect on shock. In one patient, however, in whom a retroperitoneal tumor was being resected, the pulse rate which had risen to about 140, was not reduced although no further evidence of shock was manifested. Blood was not given to this patient at this time although fluids were administered. It is doubtful whether or not even a large series of such cases would yield a conclusive answer. Although our experiences with treatment in the presence of shock were of the favorable type, the beneficial effect was much more pronounced when the extract was given prophylactically.

In an effort to obtain data on the prevention of shock in major operations, the extract was given to patients having major opera-

tions of unusual duration and severity. In a series of fifteen such cases, consisting of four gastrectomies, three resections of the rectum, two gastroenterostomies, two resections of the colon, etc.,

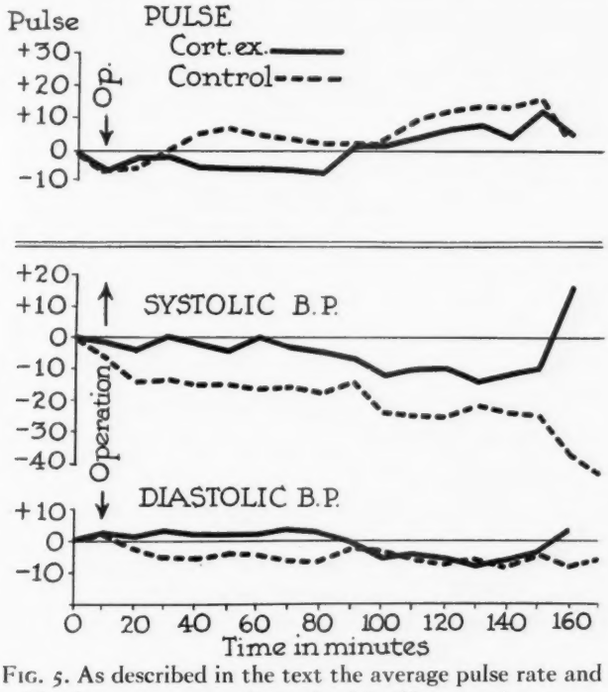


FIG. 5. As described in the text the average pulse rate and blood pressure were determined in fifteen major operations of unusual magnitude and duration, and in which cortical extract was given preoperatively (solid lines). A control series of fifteen identical operations of equal duration, but not receiving cortical extract, was studied (broken lines). Comparison reveals that there was more elevation of pulse rate, and a greater drop in blood pressure in patients not receiving extract. The diastolic pressure revealed only slight change.

we gave the drug in divided doses in amounts between 6 and 10 cc. one and a half hours and thirty minutes before operation. We went through the hospital records and found an equal number of gastrectomies, resections of the rectum, etc., with a similar type of operation, lasting the same length of time, to whom cortical extract was not given, but in whom the remaining therapy was similar. We averaged the pulse rate, and the systolic and diastolic pressure in the two series of cases. Figure 5 illustrates the differences encountered in the pulse rate and blood pressure levels in the two series. The illustration reveals a pulse rate averaging eight beats per minute lower throughout the operation in patients to whom cortical extract

was given. The systolic blood pressure averaged 12 mm. lower in patients not receiving cortical extract. In other words, cortical extract appeared definitely to maintain a slower pulse rate and a systolic blood pressure nearer the normal level. The differences in the level of the diastolic blood pressure in the two series was probably too slight to be of any significance. However, there was a slight tendency toward a lower diastolic blood pressure in the control patients not receiving cortical extract.

## SUMMARY

In an effort to determine the efficacy of cortical extract in the prophylaxis and the treatment of shock, the extract was given to animals subjected to shocking procedures and to human beings having major operations of a magnitude apt to produce shock. In animals, shock was produced by hemorrhage and by massage of the intestine with the animal under ether anesthesia. In experimental shock produced by hemorrhage cortical extract exerted a definite but slight tendency to decrease the severity of shock, particularly when the extract was given with fluids (glucose and electrolytes). Fluids alone, i.e., without cortical extract, did not significantly prevent the fall in blood pressure although the actual survival time following hemorrhage was increased.

When cortical extract was given an hour or two before institution of intestinal massage (to produce shock), the average drop in systolic blood pressure after forty minutes of massage was only 19.5 mm., contrasted with 35.3 mm. in animals not receiving extract prophylactically. Moreover, when hemorrhage of a constant rate was instituted ninety minutes after intestinal massage was begun, there was a survival time of thirty-six and five-tenths minutes in animals receiving cortical extract, contrasted with a survival time of only twenty-one minutes in animals not receiving cortical extract. When glucose and electrolytes were given in addition to extract, the effect was still more prominent, there being no drop in blood pressure after forty minutes of massage and an average of only 7.5 mm. after fifty-five minutes of massage. In other words, the beneficial effect of cortical extract and fluids (glucose and electrolytes) in prevention of shock was comparable to that which might be expected from plasma. When extract was given after shock had already been produced in animals very little beneficial effect could be demonstrated; there was little or no rise in blood pressure although further drop was slightly delayed.

Falling drop determinations showed an increase in specific gravity of blood in shock, and a decrease after hemorrhage as reported by others. Cortical extract showed a definite but slight tendency to counteract the increase in specific gravity produced by shock.

In human beings the use of cortical extract in the presence of shock was limited to a few cases due to the relative infrequency of shock, but in every instance the effect appeared to be beneficial.

In order to determine whether or not cortical extract would exert a favorable influence in prevention of shock, the average pulse rate and blood pressure was computed in a series of fifteen patients receiving cortical extract prophylactically, and upon whom major operations of unusual duration and severity were performed. From the hospital records an equal number of operations (in which no cortical extract was given), with equal number of types and duration, were obtained and the average pulse rate and blood pressure likewise determined. In the patients receiving cortical extract prophylactically, the pulse rate averaged eight beats per minute slower, and the systolic blood pressure 12 mm. higher than in the patients not receiving extract. This suggests that the cortical extract tends to minimize the changes which might be interpreted as being changes preliminary to the development of shock.

Observations on animals as well as patients showed that the extract was much more effective when given prophylactically, than when given after shock was already produced.

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## DISCUSSION

FRED W. BANCROFT (New York City): I thought it might be of interest, in addition to Dr. Cole's paper, to review briefly first what happened to adrenalectomized animals; and, secondly, to give some definite indications for the use of cortical extract.

If I may, I should like to read very briefly from an article by Dr. Edward C. Kendall, of Rochester, Minnesota, which appeared in the *Journal of the American Medical Association* recently:

"When the adrenal glands are removed from laboratory animals, symptoms of deficiency develop which may be summarized as follows: The first notable change is usually a loss of appetite, which is soon followed by nausea, vomiting, increased peristalsis, and eventually bloody diarrhea. Associated with these changes are profound weakness of the muscles and a listless stupor, or, in some animals, restlessness and marked salivation, with clonic movements and general convulsions similar to those observed in hypoglycemia induced by insulin. There is a gradual decrease in body temperature, and a decrease in the basal metabolism rate.

"Continuance of the state of adrenal deficiency is invariably associated with a decrease in blood pressure to the death level, an increase in the hematocrat reading, and a progressive decrease in the volume of the circulating blood. Soon after removal of the adrenal glands there is a marked and continuous increase in the concentrations of non-protein nitrogen and potassium and a decrease in the concentration of sodium and chloride in the blood serum."

In shock there is a pooling of the plasma in the tissue spaces with hemoconcentration. There is also present a spasm of the arterioles and smaller veins. Our purposes then are, first, to relieve the spasm of the terminal arteries, which can be done by administering sodium, and, second, if we consider the tissue space as a sponge, to use a method to squeeze the sponge

in order to get the plasma back into circulation. If we cannot actually squeeze the sponge, we should at least attempt by medication to decrease the permeability of the capillaries. (Fig. 6.)

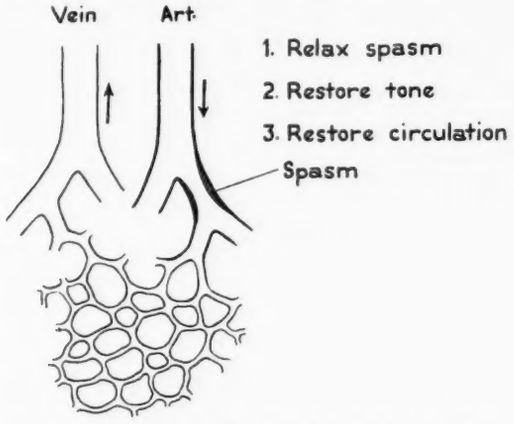


FIG. 6. Diagrammatic sketch of the capillary spaces.

It has been shown by Walter Estell Lee that in very diffuse burns, if cortin is given less plasma has to be given the patient in order to overcome the hyperproteinemia. Also, if cortin is given early the specific gravity of the plasma is increased and stays at an even level. If plasma alone is given, there is a temporary rise and then a fall in the specific gravity of the plasma. If plasma and cortin are given together, we then have a curve that rises and stays up. Also we know that the sodium will decrease our arterial spasm so that it would seem that hypertonic saline given at the same time would help, first, to relieve the spasm, and the plasma and cortin will help to squeeze the sponge and diminish the vascular permeability.

My own experience has been as follows: In a large intestinal resection, a woman's blood pressure dropped to 80/40. Our blood bank had failed us. We tried giving gum acacia, which did not bring the blood pressure up. Within twenty minutes after the administration of cortin, her blood pressure had risen to 110/80. It dropped to 105, but stayed at that level.

In another case, an abdominal peritoneal resection, the night following the morning of operation her blood pressure dropped to 80/40. Glucose did not have any effect. We were not able to get transfusion at that minute. On administration of escotin her blood pressure arose to 110.

So, as a result of my own experience, I am convinced there is a very definite need for cortical hormone in preventing and relieving delayed postoperative shock.

I have enjoyed listening to Dr. Cole's paper and am thoroughly in accord with all he has presented.

J. S. L. BROWNE (Montreal, Quebec): I have been extremely interested in this paper and in Dr. Bancroft's discussion. As I mentioned, there is a

reasonably good rationale behind the use of cortical substances in the condition of shock.

The idea of using adrenal cortical extracts for this purpose has been going on for quite a considerable period of time, gradually increasing in definiteness. It perhaps began with Swingle, who suggested as far back as 1931, I think, that the symptoms of adrenal insufficiency and those of shock were rather similar.

Cortical extracts were used clinically by Reade some time ago. He believed that he obtained an improved postoperative course in his patients after the use of cortical extracts, even in those in whom no shock occurred. Perla and his collaborators obtained good results, using desoxycorticosterone acetate and sodium chloride in preventing shock.

Dr. Cole asked me to discuss the question of the difference between desoxycorticosterone acetate and cortical extracts. Our experience has been limited, as I think I said, to the use of the intestinal manipulation method of inducing shock in rabbits. The difference has also been studied in rats by Dr. H. Selye and his collaborators. Weil, Rose and Browne found in the rabbit that the mortality could be reduced from approxmately 60 to 19 per cent using both cortical extract and desoxycorticosterone acetate together, but only to 42 per cent if desoxycorticosterone acetate was used alone. The latter is not a statistically significant reduction in mortality. Selye, Dosne and Bassett found desoxycorticosterone acetate to be ineffective in the rat.

As I pointed out, these substances were used prior to the trauma. In other words, it was a prevention rather than a cure.

I think it is very important for us to consider whether cortin will do anything which blood, serum plasma or other blood substitutes will not do. I also think it is important to consider the question of the amounts which have to be used. I would like to ask Dr. Cole what were the amounts he used.

I would also emphasize that although at the present time the cortical extracts are of greater uniformity than they used to be, still the cortical extracts prepared by various companies may not always contain the same kind or amount of cortical substances; and since it does appear, as far as certain types of shock are concerned, that the substances of the corticosterone type are more effective, this may be of importance in the results obtained.

Our own experience with patients has, I may say, not been dramatically convincing. It is extremely difficult, as you well know, to give cortin to a patient in shock without giving him the other types of therapy ordinarily recognized. It is, in fact, impossible. And when one obtains a result it is often difficult to evaluate the relative merits of the cortical extract, as compared with the results obtained when normal saline plasma, blood, etc., are used.

I think it is true to say that our most encouraging results (we have had only one or two cases) have been in infants, in which we have used 25 to 50 cc. of Wilson's cortical extract. That makes one wonder whether it is possible, as it has been so often in the past, that the doubts which have arisen regarding this method of therapy are due to the fact that our dosage level is inadequate, and that we are in the same stage with cortical extract in this therapy that we were with many other hormones in the days when they were given in perhaps a tenth of the amount really necessary, and occasionally, in a very sensitive patient, good results were obtained.

I think, too, that in certain cases, relative cortical deficiency may be the limiting factor in the development of shock. There are possibly some people who are unable to increase the amount of cortical substances put out by their adrenal when they are put to the stress of operation or trauma; or, some patients may already be putting out their maximum if they have had prolonged infection or are aged, etc. In them, one might get definite results with cortical extracts.

In the normal adult male, we will say, who is traumatized, it is questionable whether one can give an amount equal to that produced by the patient's own adrenal cortex. We know in animals that the amounts of cortical substances necessary to produce the effect in normal animals are very much greater than those necessary to make the proper restoration in the adrenalectomized animal.

It seems perfectly clear in the case of Addison's disease that one can get dramatic improvement in resistance to trauma by the use of cortical extracts, but it is much more difficult to prove it for the normal person. So while I agree there are a good many indications in which perhaps adrenal cortical extracts are beneficial, I am not sure but that we are going to have, in fact, I am sure we are going to have great controversy about it, and I wonder whether it may be because we are not using sufficient dosages.

We had a case of intracranial operation for trigeminal neuralgia. The patient went into shock with falling blood pressure. At one time the blood pressure was unobtainable. At this point, 25 cc. cortical (Wilson's) extract was given intravenously, and the blood pressure did reappear within fifteen minutes. Blood transfusion had been given continuously up to this point. It is very difficult to evaluate this case because blood and saline had also been given. However, there is a slight rise in blood pressure associated with the dose of cortical extract but I do not think that it is very significant.

In a second case a small amount (50 cc.) of concentrated serum was given. This was one of the early preparations. It produced a more severe shock than I have ever seen. It was matched with the patient's blood. This patient continued throughout about twelve hours to have a blood pressure below 80, and at various points 25 cc. of cortical extract was given with perhaps slight effect. But 500 cc. of blood was given some hours later with a dramatic rise in blood pressure which occurred immediately after. Here then

we have blood giving a very much better effect than cortical extract in the doses used.

A third case was one in which again one may say perhaps some slight effect was obtained from cortical extract. Ten cc. was given intravenously but no saline. At this point there was a sharp rise in blood pressure. This is about the only case in which one can say there was a definite effect.

In a fourth case with falling blood pressure 20 cc. of cortical extract was given and a small amount of saline with it, with some rise in blood pressure. But, as you all know, in this type of case the blood pressure is likely to rise spontaneously, and one questions just how much the treatment had to do with it.

I admit that the studies on these cases have not been as well planned as they might have been from the experimental point of view. This is sometimes difficult to do in cases of shock in which rapid and multiple therapy is, of necessity, often undertaken. I think that it is possible, quite probable in fact, that cortical extracts will be beneficial. However, I think that our doses are probably too low at the present time.

J. B. Collip (Montreal, Quebec): I am sure, due to the lateness of the hour, you do not want me to give a lecture today, but there are a few things I might say of interest in relation to shock.

This age-old subject has come very much to the fore on account of the war, and laboratories engaged in other pursuits are now in some cases turning all their attention to work upon this and closely allied topics. Work which is being done under government auspices on this subject cannot be talked about by the workers until their results have been reviewed by a sub-committee of publications.

There are a number of generalities, upon which I may speak. The question as to whether suprarenal products will be of value is certainly very much to the fore, and the work reported by the speaker today would indicate that cortin (cortical extracts containing many hormones) has got a place in the treatment of shock.

I think that one of the finest pieces of work which has been published on this subject is that by Dr. Swingle, of Princeton. Dr. Swingle had the courage to use his very precious adrenalectomized dogs. These animals are particularly susceptible to various procedures which produce shock, procedures which have to be applied very, very vigorously in normal animals, such as injury to muscle or injury to intestines.

Swingle pointed out that it is only necessary to tap adrenalectomized dogs' muscles very lightly for a short period of time to send them into profound shock. If the dog is not treated, the blood pressure falls steadily, and the animal dies in a few hours, so he has an ideal preparation to test various forms of therapy.

He showed very conclusively that if he gave, starting the night before, two injections, I think, at four hours apart, 5 mg. of desoxycorticosterone

in oil, followed by another injection in the morning on which the experiment was performed, he could absolutely counteract the effect of muscle trauma producing shock in these animals.

Cortical extract, however, is much more soluble and when given as a solution he found by injecting it when the blood pressure was as low as 40, that he could almost invariably restore the animal to normal.

When, however, he proceeded to do much the same type of experiment, but using intestinal trauma, (gentle stripping of the intestine) the animals so treated went into profound shock and died within a few hours. He got absolutely no recovery when he used desoxycorticosterone, but cortical extract gave protection. Thus he did show a remarkable distinction (at least under the conditions with which he was working) between the effect of desoxycorticosterone in restoring normalcy after muscle trauma, whereas it was perfectly useless in counteracting shock produced by stripping the intestines.

As Kendall has pointed out, there are something like eight individual steroids which have been isolated from the suprarenal cortex, all of which are presumably present in cortical extract, but in varying degrees. It is even possible that some of these cortical steroids are definitely antagonistic to each other. There is a small amount of desoxycorticosterone in suprarenal cortex which has been extracted and identified and which is presumably present in all, but corticosterone and Kendall's Compound E, apparently are the things which we want. Desoxycorticosterone has its use but it has its limitations. Undoubtedly, blood substitutes will have their place in the treatment of shock looking at it from the laboratory angle.

Recently, some of the work going on in my laboratory has been released for publication, and if you care to listen to Dr. Noble for two or three minutes, he might tell you something about it.

R. L. NOBLE (Montreal, Quebec): It is interesting to note that the criteria used in the effectiveness of cortical extract in the treatment of shock as related to the vascular system, the cardiovascular system, such as the pulse rate. As I mentioned the other day, it seems that the fundamental mechanism which goes wrong in shock is the loss of plasma into the tissues, and if it were possible to correct this fault, an effective treatment of shock might be available.

We have some experimental results using stimulation of the adrenal glands and studying the effects on hemoconcentration which tend to show that the adrenal cortex has an effect in aiding the return of fluid from the tissues, back into the blood stream.

In these experiments we were using histamine, which is a chemical substance and has an advantage that it can be used quantitatively. We were not using it because we believe that it is the causative factor in shock, but following this injection a normal rat shows hemoconcentration in the first half-hour of 30 or 40 per cent. This rapidly returns to normal in approx-

imately six hours. If it is used on an adrenalectomized animal, the degree of hemoconcentration is slightly greater; but the blood remains concentrated for six hours and even up to twenty-four hours, showing the tissues apparently hold onto the plasma in the absence of the adrenal cortical hormone. But after treating these animals with a satisfactory extract, it is possible to have them behave as normal animals; that is to say, they show hemoconcentration initially for thirty minutes, and then the plasma returns rapidly to the blood stream, so the blood volume returns to normal.

This is quite a definite indication, I think, of the value of adrenal cortex in the mechanism of this kind. However, as pointed out before, the normal animal is a very definite proposition. We have not been able to give a normal animal any sort of treatment and prevent this hemoconcentration from occurring, although it is possible to restore the adrenalectomized or hypophysectomized animal so it behaves like a normal animal.

Warren H. Cole (closing): I would first like to thank the discussers. Dr. Browne asked a question regarding dosage; we used ½ of 1 cc. per kilo of body weight in animals, and at times repeated it in an hour or so depending on the type of experiment being performed. In adults we did not give such large doses, varying the amount from 4 to 20 cc. I am convinced the various products obtained would vary tremendously in their active principles, but I believe that we were fortunate in having a fairly potent product. We used 4 to 10 cc. for a prophylactic dose and up to 20 cc. for active treatment of shock. As much as 60 cc. or more may be given in twenty-four hours, since the extract does not appear to be toxic even in such large doses.

# RÉSUMÉS OF CLINICS AT MONTREAL GENERAL AND ROYAL VICTORIA HOSPITALS

## MONTREAL GENERAL HOSPITAL

1. *Acromioclavicular Dislocation* (*Dr. D. W. Ramsey*). Movement at the acromioclavicular joint is a necessity to the well functioning shoulder. These movements are of two kinds: (1) A gliding motion of the articular end of the clavicle on the acromion, and (2) rotation of the scapula on the clavicle. Repair of the dislocation then aims at restoration of anatomical position with maintenance of function.

The acromioclavicular joint is a true joint having articular cartilages with or without an articular disc and a capsule. Above the capsule is the acromioclavicular ligament. The joint is greatly strengthened by the coracoclavicular ligament which is made up of two parts, viz., the conoid and trapezoid ligaments.

Dislocation is brought about most commonly by a fall on the shoulder while the body is in motion, or by a weight falling on the tip of the shoulder. This causes a twisting motion of the scapula in such a manner that the axis of rotation lies between the acromion and the coracoid process. The acromion is pulled downward and the coracoid process impinges on the clavicle, pushing it upward so that the lateral end of the clavicle rides over the acromion. This displacement is aided by the slope of the joint, the articular surface of the clavicle facing downward and outward.

Two degrees of dislocation are described: (1) A subluxation as a result of tearing of the acromioclavicular ligament and (2) a complete dislocation when all the ligaments are torn.

On March 3, 1941, a man fell with a ladder to the floor, landing on his right shoulder. He was brought to our surgical out-patient department where examination showed that he had limitation of movement at the shoulder due to extreme pain. The tip of the shoulder was depressed and the outer end of the clavicle was quite prominent. Tenderness was marked in the region of the acromioclavicular joint.

An *x*-ray was taken and showed the dislocation to be quite complete. Strapping was applied but this proved unsatisfactory and he was admitted to the ward on March 8.

After a two-day skin preparation with E.A. plus iodine, the joint was exposed by an S-shaped incision over the front of the shoulder. It might be mentioned here that as soon as the anesthetic was given the dislocation could easily be reduced by pushing upward on the elbow. Two drill holes were then made through each of the adjoining bony parts of the joint. A wire mattress suture was applied through the drill holes in such a manner that the wire bridged the joint underneath the capsule but not above. The capsule itself was repaired by No. 2 chromic catgut. The operation was completed by applying elastoplast strapping after the method of Watson-Jones.

*X*-ray postoperatively showed complete reduction. The elastoplast support was maintained for five weeks. After nine weeks passive movement was fairly good, but active movements up to that time have not been fully regained. It might be added that he is a compensation case.

2. *Prevention of Slip in Spiral Fractures of Both Bones of the Leg* (*Dr. L. H. McKim, M.D.*). The injury specifically referred to is the very common spiral fracture at or about the junction of the lower and middle thirds of the tibia. The mechanism of production is of the rotation or torsion type. The line of fracture runs obliquely upward and outward and, in the anteroposterior view, usually points to the fibular fracture in the upper third of that bone. (Fig. 1.)

It is not the intention of the author to discuss the advisability of treatment of this injury by the application of plaster of Paris cast nor to compare the results so obtained with those by other more complicated methods. Under certain circumstances, plaster fixation is almost the only available form of treatment and may be the method of choice for various reasons.

Every surgeon, who has treated this injury, has observed the tendency of the lower fragment to slip upward and usually outward. This deformity tends to occur as soon as the cast becomes even slightly loose.

Previous to the introduction of our present method, we were able to prevent slipping only by early (and frequent) changes of the cast under anesthesia. We have found that the method at present in use not only reduces the number of reapplications of the cast but also adds very materially to the comfort of the patient by relieving the pain so often complained of in the region of the ankle.

In order to clarify the principles on which this treatment is based, it may be well to make certain general statements with which most surgeons will agree. These are: (1) If plaster fixation is to be made use of, this injury must be treated with a close fitting cast extending as

far up the thigh as possible. (2) Displacement tends to occur as soon as the cast begins to become loose. (3) Casts become loose (a) from lessening of primary swelling and edema, (b) from atrophy of the

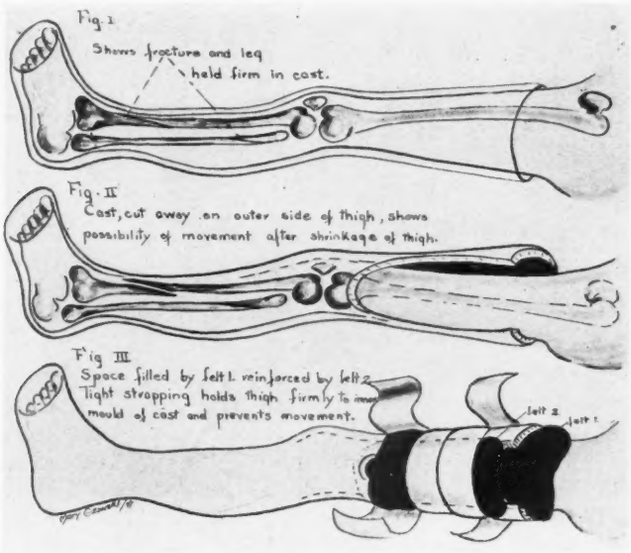
Fig. I
Shows fracture and leg held firm in cast.
Fig. II
Cast, cut away on outer side of thigh, shows possibility of movement after shrinkage of thigh.
Fig III
Space filled by felt 1. reinforced by felt 2
Tight strapping holds thigh firmly to inner mould of cast and prevents movement.
felt 2
felt 1

FIG. 1. Diagrammatic sketch of mechanism of displacement and method of correction.

muscles enclosed by the cast. (4) From this it follows that the greatest degree of loosening occurs in the thigh when muscular atrophy is very rapid. The calf muscles, by their shrinkage, also cause an appreciable space soon to become apparent between the soft tissue and the cast in the lower leg region. (5) The presence of the many superficial bony prominences about the knee makes this the region where the *least* loosening occurs.

A consideration of the above mentioned items will give an instant appreciation of the factors concerned in the displacement of the tibial fragments (for practical purposes, the fibula may be disregarded since the fracture is in the upper third and is of little importance, apart from the extremely rare complication of involvement of the peroneal nerve in the callus). We have thus the following condition of affairs: (1) The upper tibial fragment enclosed in a more or less loose cast due to shrinkage of calf muscles; (2) the knee region, where very little loosening occurs, forming a relatively firm point of leverage; (3) the femur, forming the long arm of a lever, transmits forceful movements to the upper tibial fragment.

The direction of possible movements of the upper tibial fragment should be considered. It will be immediately understood that, if the

above mentioned theory of the knee region acting as the point of leverage is admitted, any lateral movement of the femur will cause the lower end of the upper tibial fragment to be displaced medially.

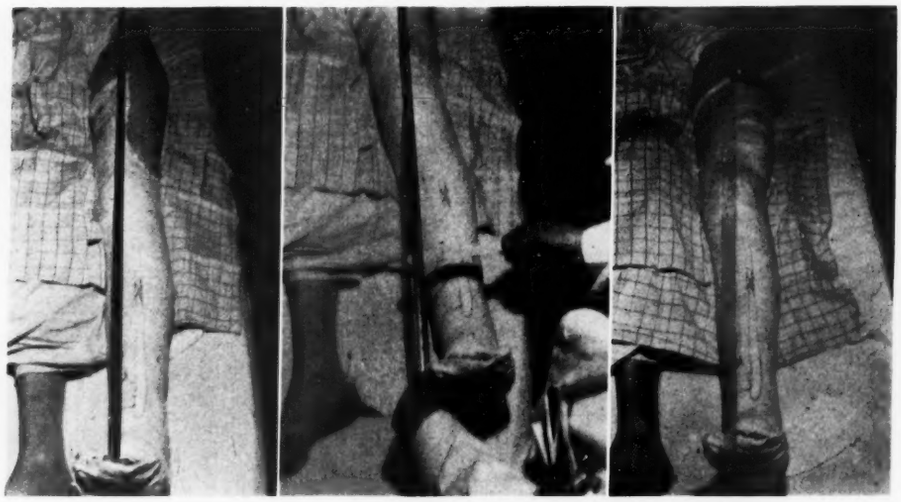

FIG. 2. FIG. 3. FIG. 4.

FIG. 2. Cast cut away on outer side above knee. Note normal line of weight bearing, anterior superior spine, middle of patella and second metatarsal bone.

FIG. 3. Leg abducted. Cast allowed to fall away from inner side of thigh. Upper two points of line of weight bearing same as in Figure 2. Note point of fracture now three inches external to line and a possibility of medial displacement of lower end of upper tibial fragment.

FIG. 4. Felt pads applied and thigh fixed. Note re-establishment of line of weight bearing.

The opposite movement, medial displacement of the femur, will, of course, cause the upper fragment of the tibia to be displaced laterally. Real displacement in this direction is impossible since the slope of the fractured surfaces could only be the more closely approximated by such a maneuver. It follows, therefore, that the secret of keeping the fractured surfaces in close contact lies simply in keeping the femur as close as possible to the medial wall of the cast. This explains why the simple method adapted for the prevention of lateral movements is so effective.

It may be noted that the leverage movements described operate only in a lateral or medial direction. The mechanism does not apply as regards anterior and posterior movements because of the natural hinge of the knee joint.

The method consists in the incorporation of a firm plaster mould in the medial wall of the cast. This mold must be of considerable strength and should extend from the foot to the upper third of the

thigh. As soon as any shrinkage of the thigh muscles occurs, usually in five to seven days, the outer or lateral part of the cast, from the knee upward, is cut away and the thigh firmly fixed to the thick medial aspect of the cast by applying thick pads of felt to the outer side of the thigh and fixing them in place with circular straps of adhesive. These straps hold the thigh firmly against the thick medial wall of the cast and must be readjusted at short intervals as greater shrinkage of the muscles occurs. (Figs. 2, 3, and 4.)

There is nothing new in the principle involved in this method. All surgeons, who have had extensive experience in the use of the Thomas splint, know that the secret of control of fragments (either in the upper or lower leg) lies in keeping the inner side of the ring closely approximated to the inner side of the thigh. The inner bar of the Thomas splint more or less corresponds to and parallels the direction of the leg bones when the splint is properly used. This is not true of the *outer* bar of the splint owing to the various sizes of the ring. It is often advisable to use slight lateral traction on the upper end of the splint by means of a pulley at the side of the bed to maintain close contact between the thigh and the inner part of the ring. The similarity of the principle involved is apparent.

3. *Fracture Dislocation of the Tarsal Navicular (Dr. R. R. Fitzgerald).*

Case Report: The patient, a miner, thirty-one years old, fell from a scaffold a distance of about sixty feet, lighting on a pile of loose rock. The principal injury consisted of a comminuted fracture of the left tarsal navicular (scaphoid) bone, with dorsal displacement of the wedge-shaped major fragment. After manual traction and plantar flexion, the bone could be pressed down into its bed, but as soon as firm pressure was released, it again sprang up on to the dorsum of the foot. This largest portion of the bone was wedge-shaped, with an intact dorsum, and a fragmented plantar part, where the strong attachment of the tibial posticus and long and short plantar ligaments anchored the broken pieces deep in the navicular space.

The problem was to open the navicular bed by distraction, and to hold it open by mechanical fixation for the period of ten weeks or so that are necessary for the replaced fragments of the navicular to solidify into a bony mass that can again take its place in the arch of the foot.

In this patient the traction was obtained by five stainless steel wires, one passed through the soft tissues of the tip of each toe and wound over a steel bar. The counter traction came from a 5 mm. steel nail driven through the calcaneus. To overcome the pull of the muscles, a distracting force of fourteen pounds was used in the long axis of the foot. The pieces of the bone were then gently pressed into the open space.

A second 5 mm. nail was then driven through the bases of the metatarsals, and the foot and leg embedded in a nonpadded plaster walking boot. When the plaster had set, the wires were removed from the toes and the walking heel adjusted. The patient began to walk on the third day, and the check films show the reassembled bone sitting in its natural place between the talus and cuneiforms. He will be instructed to walk as much as possible to discourage demineralization of the bones, and in ten weeks the nails and plaster will be removed.

This case is discussed because of its rarity, and because the method here described has apparently been successful.

4. *Intertrochanteric Osteotomy for Nonunion of Fracture of the Neck of the Femur* (*Dr. J. A. Nutter*). Fracture of the neck of the femur frequently yields to various pegging or nailing operations with the production of bony union. Even after months of delayed or even nonunion, such treatment may be successful. Unfortunately, the production of bony union is by no means a guarantee of good function and freedom from pain. Months or even years after the original fracture the development of a dead head (with softening and deformity) or of painful osteo-arthritis may not uncommonly occur. An operation which, it is thought, may be followed less frequently by these complications was demonstrated. This operation was intertrochanteric osteotomy just above the level of the lesser trochanter, following which the upper end of the femoral shaft is pushed inward to lie snugly beneath the head of the femur, thus providing end bearing. The osteotomy is obliquely downward and outward to encourage union of the great trochanter. In some cases the non-union neck fracture is healed, but in any case the shaft and trochanter together form a crutch under the head which gives good weight bearing, and may even form a new joint.

A very heavy woman (about 220 pounds, age fifty-nine) was shown who had had such an operation a year previously, two and one-half years after hip fracture, without any union. This patient walked around very comfortably with a stick, suffering very little pain and doing her own housework. Movement was excellent and shortening negligible. This operation, developed particularly by McMurray, of Liverpool, has proved so successful in cases of non-union that it is now being used in fresh hip fractures, particularly those near the acetabulum. An illustrative case was shown (woman age sixty-one) operated upon last August, now walking with good movement and very little disability in spite of non-union of her fracture.

It is to be noticed that such an operation requires very little apparatus and can be done in twenty to thirty minutes. A cast should be worn for a few months in a position of slight hip abduction and flexion and slight knee flexion.

*5. Abstracts of Discussions Relating to Traumatic Shock and Storage of Blood (Dr. J. B. Collip).* The discussion was opened by Dr. J. B. Collip who outlined briefly the work of the National Research Council, with particular reference to the support of medical research relating to problems arising as a result of the war. He indicated also that a very close liason had been established between the Associate Committee on Medical Research of the National Research Council of Canada and the various Committees of the National Research Council in Washington dealing with medical matters.

The discussion was continued by Dr. R. L. Noble and Dr. O. F. Denstedt.

*Shock. Abstract of Discussion by Dr. R. L. Noble:* Some of the difficulties in evaluating shock in clinical cases were discussed. The grouping of cases of comparable severity for determining therapeutic procedures is difficult and complications such as hemorrhage, infection and intravenous administration of fluid may be encountered. Many difficulties are also present in attempting to produce a quantitative degree of shock experimentally. Most methods of applying direct trauma are associated with hemorrhage and anesthesia and are not quantitative. The experimental findings which have been used as an indication of shock are often open to criticism. Blood pressure alterations may be influenced by anesthesia. Blood volume measurements by the dye method are affected by loss of dye through the capillaries in a shocked animal. Hemoglobin values are influenced by hemorrhage. Some biochemical changes may be misleading. The actual death of the animal is stressed as the most accurate end point in experimentally induced shock. The factors suggested for the cause of death in shock were reviewed and the different pictures following hemorrhage and shock were contrasted. It was suggested that the discovery of the factors controlling the shift of fluid in the blood and tissues would be of great value. It is possible that if one could cause hemodilution to occur as it does after hemorrhage in a case of shock a cure might be effected. The observations which suggested that adrenal cortical extracts might be of value in shock were noted. It appears, however, that the normal animal may not respond in the same way as the adrenalectomized animal. The therapeutic use of

dried serum in shock was discussed. Hemoconcentration is apparently reduced, but in evaluating such treatment the time after and degree of shock should be considered, since hemoconcentration may be followed by hemodilution during recovery without any form of treatment. Experimentally, relatively enormous amounts of intravenous fluid may leave the blood stream. There is no reason why transfused isotonic serum should not escape to the tissues when the normal plasma of the blood stream has already done so, in cases in which shock is severe.

*The Preservation of Blood. Abstract of Discussion by Dr. O. F. Denstedt:* Numerous methods of preservation of blood by refrigeration have been described in the literature. All involve the use of so-called "preservative" or diluting fluids containing an anticoagulant such as sodium citrate and sometimes sodium chloride, glucose and other salts. A comparative study of the various methods recommended has been carried out in the Department of Biochemistry at McGill University and an improved method has been developed which makes possible the preservation of whole blood for several weeks.

From the study made it has been shown that, in addition to temperature and the composition of the diluting fluid, the proportion of blood and diluent has a marked influence on the stability of red cells during storage. Optimal stability, and hence preservation, is obtained when blood is diluted as follows and stored at 4°C.:

Blood—5 parts: isotonic (3.2 per cent) sodium citrate—1 part: isotonic (5.4 per cent) glucose—1.5 parts.

In this mixture the blood is diluted with half a volume of diluent (1:½). It is important that the diluting solution be isotonic with normal plasma. The addition of sodium chloride has always been found to impair preservation and the use of citrate alone is inferior to the citrate-glucose mixture.

Because of the difference in stability of individual bloods there is no one diluent which gives optimal preservation with all bloods. The above mixture and dilution have been found most satisfactory for bloods in general. The majority of bloods are not affected greatly in stability if the proportion of blood to diluent is varied between 1:¼ and 1:1. Dilution with more than an equal volume of diluent, however, renders the cells less stable to isotonic saline and to fresh plasma even though they may remain intact during storage.

As yet no method has been found for preventing the slow formation and precipitation of fibrin in blood or plasma during storage.

This process occurs regardless of the nature of the anticoagulant used and is more pronounced when "decalcifying" agents such as citrate, and antithrombin substances such as heparin, are used together than with either alone. The rate of fibrin formation is retarded by dilution of the specimen. It is much less in the dilution recommended above than in the $1:1\frac{1}{10}$ blood-citrate mixture used in many hospital blood banks.

It has now been established that red cells (blood) stored up to eighteen days survive and apparently function as well as fresh blood after transfusion. Blood stored for longer periods, although efficacious, is destroyed more rapidly in the recipient. It is anticipated that improvement in methods of preservation will extend the useful storage period. Cell survival studies on blood preserved by the method outlined above, are in progress.

6. *The Amniotic Graft* (*Dr. B. Alexander*). Destruction of large areas of conjunctival mucous membrane by trauma or disease, invariably requires repair by replacement. The use of skin, while providing unlimited amounts, has the disadvantage of its pale, dead-white color, the frequent presence of hair and a constant troublesome desquamation, which gives rise to a persistent irritation and an objectionable odor.

The ideal material for replacing conjunctival mucous membrane is mucous membrane itself. The amnion, a thin transparent, silvery, tough mucous membrane of great vitality and of few vessels, seems to be an ideal medium for use in the plastic surgery of mucous membranes. Its single layer of cuboidal cells is transformed into a stratified squamous noncornified epithelium, which later becomes indistinguishable from the surrounding conjunctiva.

The case presented showed the results a year after the repair of the outer half of a traumatic, contracted right socket by an amnion graft. The fornices were reformed, the color and appearance indistinguishable from the rest of the conjunctiva and the ability to wear an artificial eye was achieved.

7. *A Method for Handling High Intestinal Fistulas* (*Dr. E. A. Macnaughton and Dr. C. H. Crosby*). The presentation of this subject before a group of traumatic surgeons may be explained by stating that fistulas *do* result from trauma to the intestine in certain cases, be that trauma operative or otherwise.

The apparatus which is used in this method of treatment provides us with an extra-abdominal mechanical anastomosis, between the bowel above the fistula and the part distal to it. The bowel contents

of the upper loop are removed mechanically and automatically transferred to the lower loop without any spilling. They are fed slowly into it so that they are readily absorbed.

Consequently, there is no further depletion of body fluids nor electrolytes and the loss of digestive juices which may total many liters daily is completely eliminated. There is no digestion of surrounding skin.

The patient takes fluids and nourishment by mouth freely, the only precaution being that the fluids be clear so that the apparatus is not blocked by solids. Milk cannot be given as it is coagulated in the stomach.

The apparatus can also be used to anastomose a fistula, deliberately formed, as the first stage of a two-staged resection and anastomosis. When the patient's condition is poor, as it may be in gangrene of the bowel or extensive war lacerations, he could be saved the shock of the more time-consuming one-stage operation by this suggested two-stage method.

The apparatus is activated by continuous suction and its construction is simple. A fenestrated rubber tube five or six inches in length and of a diameter which is easily accommodated by the lumen of the bowel is inserted into the proximal or afferent loop and held in by tapes tied about its outer end secured to adhesive strips on the sides of the abdomen. Into this "well" is inserted a soft rubber catheter which has had several additional small openings made in its terminal two to three inches. This catheter must not fit tightly into the "well." This part is similar to the tip of an abdominal suction.

This catheter is connected by rubber tubing to the top of the glass reservoir which is a tube approximately twenty inches in length and of one and one-fourth inches inside diameter. From the bottom another tube leads directly to another soft rubber catheter which is inserted for almost its full length into the distal or efferent loop of bowel.

From the top of the reservoir another tube leads to suction. With peristalsis of the bowel, fluids flow into the well and the suction causes small amounts of fluid to rise, alternately with air, in the afferent tube and to spill over into the reservoir. This continuous column of fluid in the reservoir and efferent tube is heavier than the air and water in the afferent tube, so its weight causes the fluids to flow slowly and continuously into the efferent loop of bowel. By connecting a douche can to the afferent tube through a Murphy drip, additional nourishment as glucose solution can be fed directly to the

bowel. The apparatus requires little attention once it is set in operation.

When the fistula is too small to take a tube to serve as a "well" it may either be dilated to accommodate one or the fenestrated catheter only may be inserted into the fistula.

If it is impossible to pass a catheter into the lower loop, a jejunostomy should be performed to receive the efferent catheter.

Certain fistulas will heal completely with this treatment. Others will require intra-abdominal anastomosis when the patient's condition has sufficiently improved.

Dr. Crosby then presented two cases in which this method of treatment had been employed and resulted in a successful outcome. These cases illustrated the rapid improvement in the patient's general condition which follows the institution of this method of treatment.

8. *March Fracture Complicating Hallux Atavicus (Dr. J. W. McKay).* Hallux atavicus (Morton) is a structural defect of the foot characterized by a short mobile, abducted first metatarsal segment. This defect is an atavism.

The hallux of the monkey and ape is abducted, mobile and short. The function of the ape foot is prehension as well as the support of the body weight. The persistence of this atavism in the human produces a structurally defective foot.

The defect is compensated for by muscular action and by thickening of the second metatarsal bone. If compensation fails, pain develops in the foot. The pain may be clinically identified as metatarsalgia, march fracture, Deutschlander's disease or Kohler's disease of the second metatarsal. These diseases have a communal symptomatology and hallux atavicus is the predisposing cause.

To demonstrate hallux atavicus, an anteroposterior *x*-ray film was made of the foot.

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9. *The Relation of Histamine to Shock (Dr. Fram Rose, M.D.).* The marked similarity between the effects of large doses of histamine and the symptoms of traumatic shock led to the theory that the absorption of histamine or some similar substance might be the cause of traumatic shock. The histamine theory of shock was rejected, however, by many workers because an increase of histamine in the blood could not be demonstrated in traumatic shock.

It has recently been shown, however, that in burn shock and in shock due to trauma or surgical intervention there is a marked decrease in the histamine content of the blood. This finding, contrary to the original conception that the histamine content of the blood must be increased during shock, may be explained on the basis of previous work in which it was shown that in certain allergic conditions, i.e., angioneurotic edema and dermatographia, there is a decrease of blood histamine correlated with the edema and wheal formation. A decrease during such conditions is considered to be of more significance than an increase of blood histamine. This view is supported by the observation that following the injection of histamine there is a decrease in the blood histamine as symptoms are produced.

It may be that the low histamine in such conditions reflects a tendency to a loss of plasma from the blood stream such as occurs in shock. The decreased content of the blood histamine in such conditions, it is suggested, reflects a tendency to a loss of plasma from the blood stream into extravascular tissues.

10. *The Treatment of Nail Punctures* (*Dr. H. S. Dolan*). Forming a large percentage of accidents in construction where wood forms and trestle work are used are nail puncture wounds of the feet. Nail punctures may be very minor or they may be very serious, or what was a very minor injury at first may become very serious, owing to blockage of the entrance of the wound by the inverted skin flap and the sealing-in of micro-organisms with resulting local abscess formation or cellulitis. At the Beauharnois power development, where the statistics for this report were collected, prevention of this type of injury was carried out at all times. All lumber containing nails was piled. The men were instructed to wear heavy-soled shoes, but the very nature of the soil through which the canal was built necessitated the frequent wearing of long rubber boots, with the result that nail punctures were quite common.

On a construction work in a twenty-month period the daily average of men employed was 2,106. The total man hours were 19,430,992. The work was carried out under all sorts of weather conditions, winter and summer. During this period there were 3,401 nail punctures, a very large percentage of which were in the feet. They comprised 40.85 per cent of the total accidents, minor and major, which took place during the construction. It is interesting to note here that minor accidents, such as sprains, puncture and

lacerated wounds, and foreign bodies in the eye, comprised 93.6 per cent of the total accidents. There were in all 8,306 accidents.

But it is principally the nail punctures of the feet that are of interest to us in this report. In the total of 3,401 punctured wounds there were nine cases in which there was a loss of time, a total of thirteen and one-half days, that is, 0.21 per cent of the total lost this time. In these nine cases one man lost three days and he did not report the accident to his foreman until four days after the accident and then only because the foot was painful. On examination there was infection sealed in the track of the puncture and hot fomentations cleared this up in three days. The other patients lost, on the average, one day each and this because the area was painful. None of the patients were eligible for compensation for the loss of time, nor was there any resulting disability.

The procedure laid down to be carried out in all cases of this type was as follows: As soon as the workman suffered a nail puncture of his foot or hand he reported immediately to his foreman. Here the workman's responsibility ended and it became the duty of the foreman to send the man to the nearest divisional doctor immediately. No first aid was given on the job except to cover the wound with a sterile dressing and bandage.

On reporting to the doctor, the wound was examined, the skin cleansed with iodine, 2.5 per cent and the skin area for 1 to 2 mm. around the puncture wound was cut away with a sharp scalpel, removing at the same time the flap of the skin which is always inverted into the nail track. This gives sufficiently free access to and from the nail track. The same result may be obtained by making a crucial incision at the entrance wound and turning out the flaps and cutting away the edges. The wound was then examined for any foreign material, such as a piece of clothing, which may be carried in, especially by a rusty nail. The nail track was then swabbed out along its whole length with 5 per cent iodine by means of absorbent cotton on an applicator. A dry dressing or gauze soaked in alcohol was applied externally and the man reported for work. He reported to the doctor the following day, when the superficial wound was cleansed and a dry dressing applied. Few cases required such supervision for more than three or four days.

The objects of cutting away the skin around the puncture wound, thus forming an inverted funnel of the wound, are to allow drainage, to remove the flap of skin which is always inverted, to allow for

proper exploration of the wound for foreign bodies and lastly to permit sterilization of the track.

While this treatment may seem, at first sight, to be drastic, yet if one receives these patients a short time after the accident there is a certain anesthesia of the part which reduces the discomfort of the treatment and the results obtained in this large series justify, I think, the means adopted.

11. *Injuries about the Shoulder Joint* (*Dr. H. F. Moseley*). A colored moving picture occupying thirty-five minutes was shown, illustrating interesting lesions about the shoulder. This film included the diagnosis, operation and end result of a case of complete rupture of the supraspinatus tendon, also of a large calcified deposit in the same situation. Cases illustrating the mechanisms of the various parts of the shoulder girdle were shown, such as, a case of complete fixation of the scapula, a case of removal of the sternal half of the clavicle, two cases of adherent subacromial bursitis, and a case of ablation of the greater part of the trapezius and rhomboid muscles for actinomycosis.

12. *The Rôle of the Adrenal Cortex in Resistance* (*Dr. Paul G. Weil, M.D.*). The adrenalectomized animal is much less resistant to histamine and other toxic agents than the normal animal. One of the features of the response of normal animals to a nonlethal damaging stimulus is a hypertrophy of the adrenal cortex. The reduction in mortality in normal animals treated with adrenal cortical extract before their exposure to a lethal shocking stimulus such as severe intestinal manipulation is greater than in nontreated controls.

Using a method for the determination of cortin in human urine in a study of patients with infection and other forms of damage such as after burns and following surgical operation it has been found that cortin is excreted in the urine of such patients; cortin is not normally present in the urine. The appearance of cortin in the urine of conditions of damage is considered to be a manifestation of an increased secretory response of the adrenal cortex to damage.

The rôle of the secretion of the adrenal medulla in the defense mechanism of the organism was pointed out by Cannon. The results of investigations mentioned herein tend to suggest that the secretion of the adrenal cortex also forms part of the defense mechanism of the organism.

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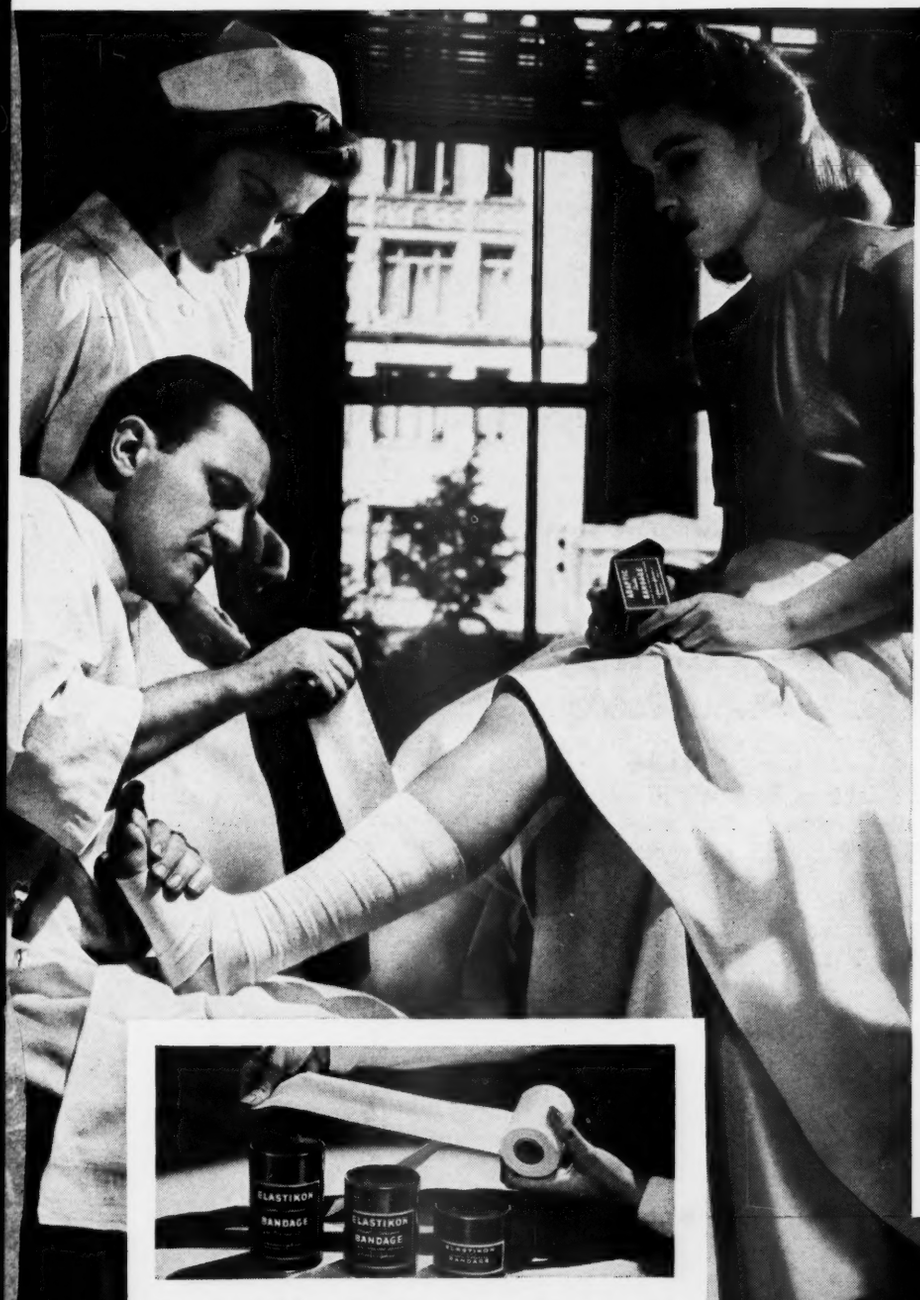

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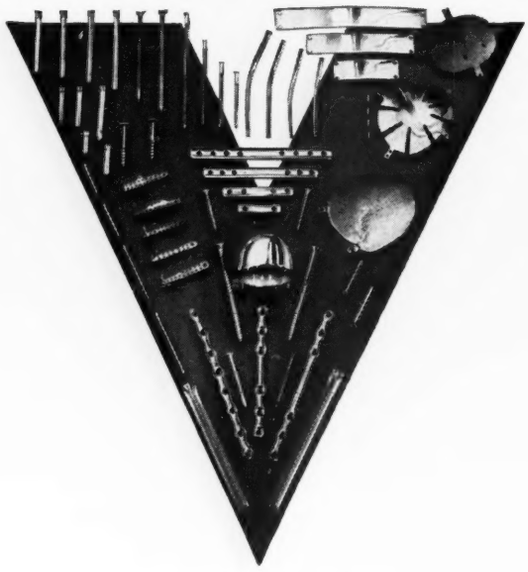

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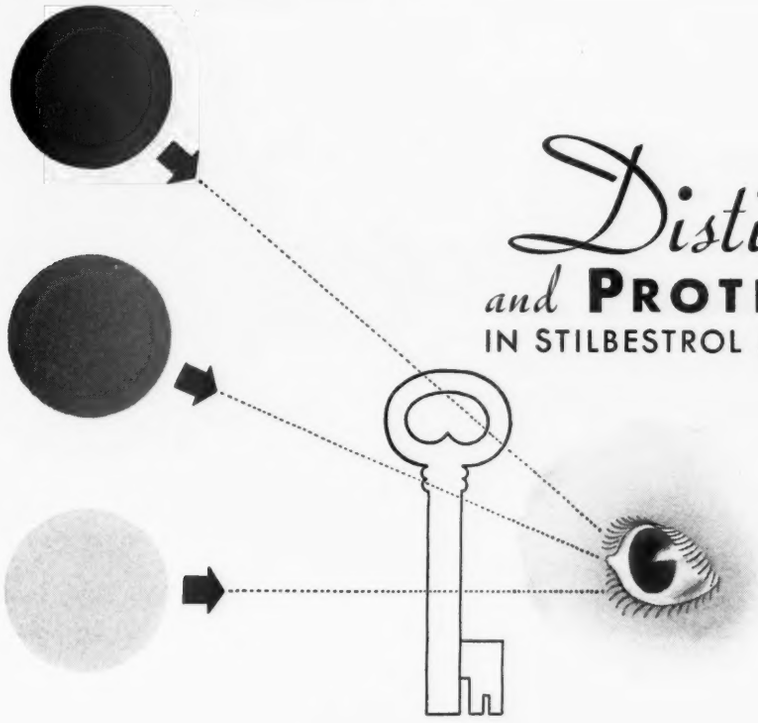

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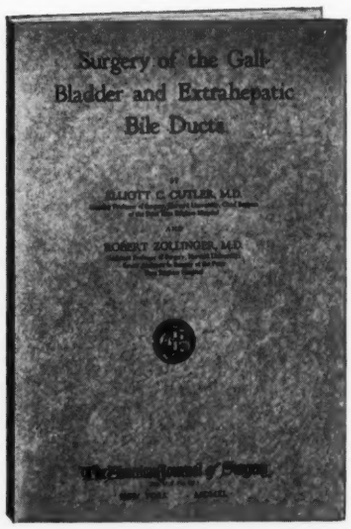


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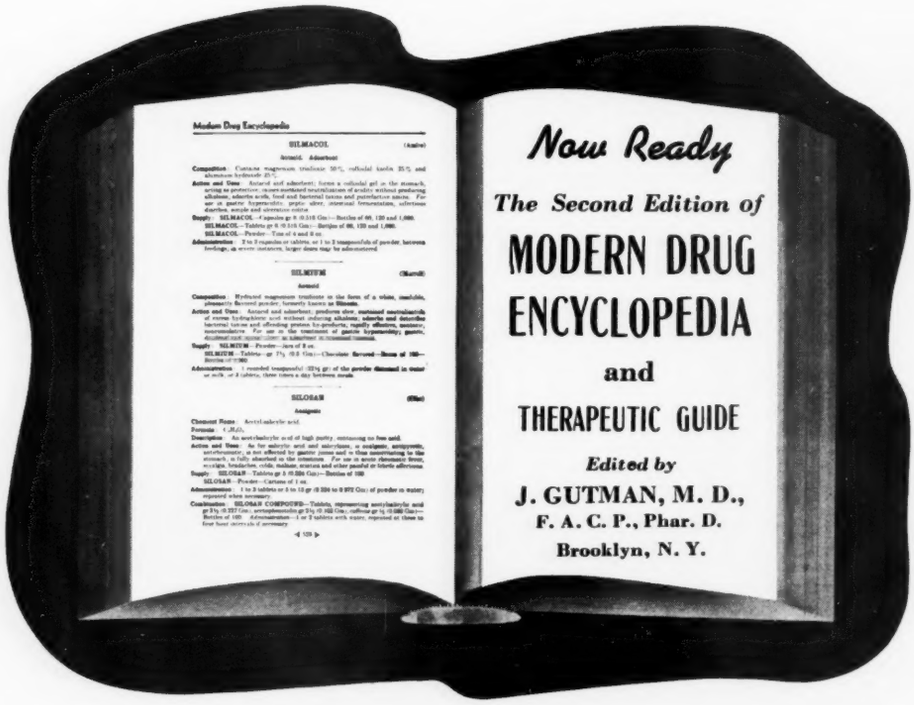


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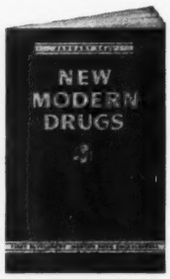

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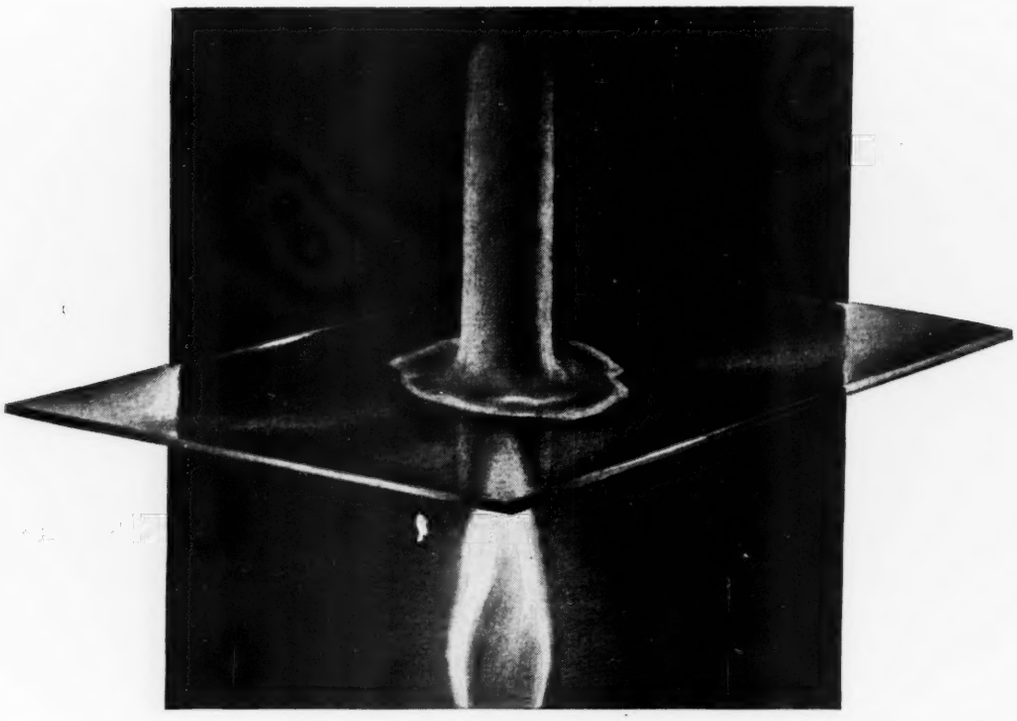

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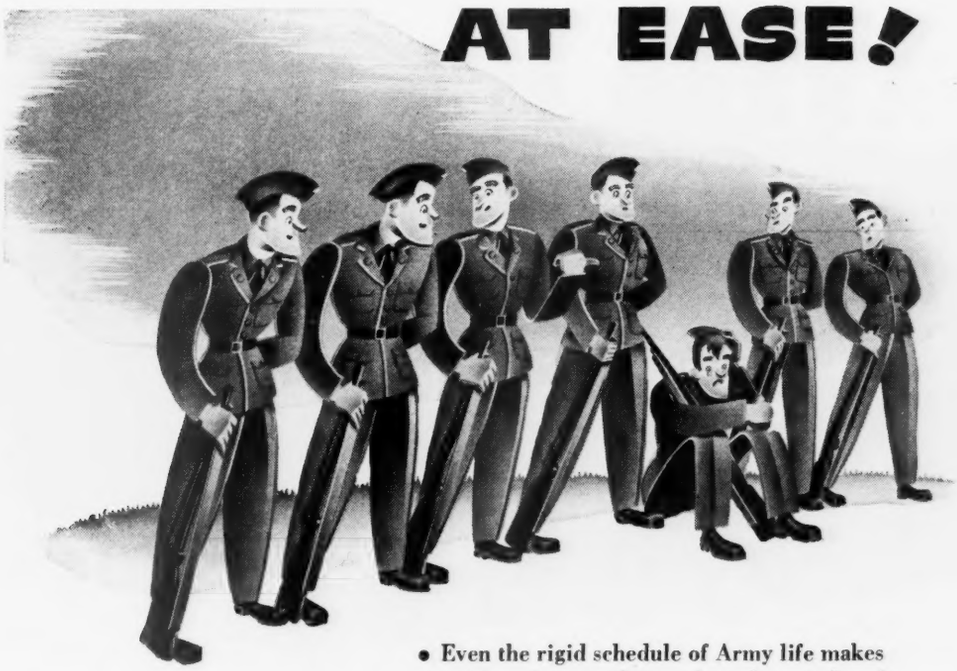

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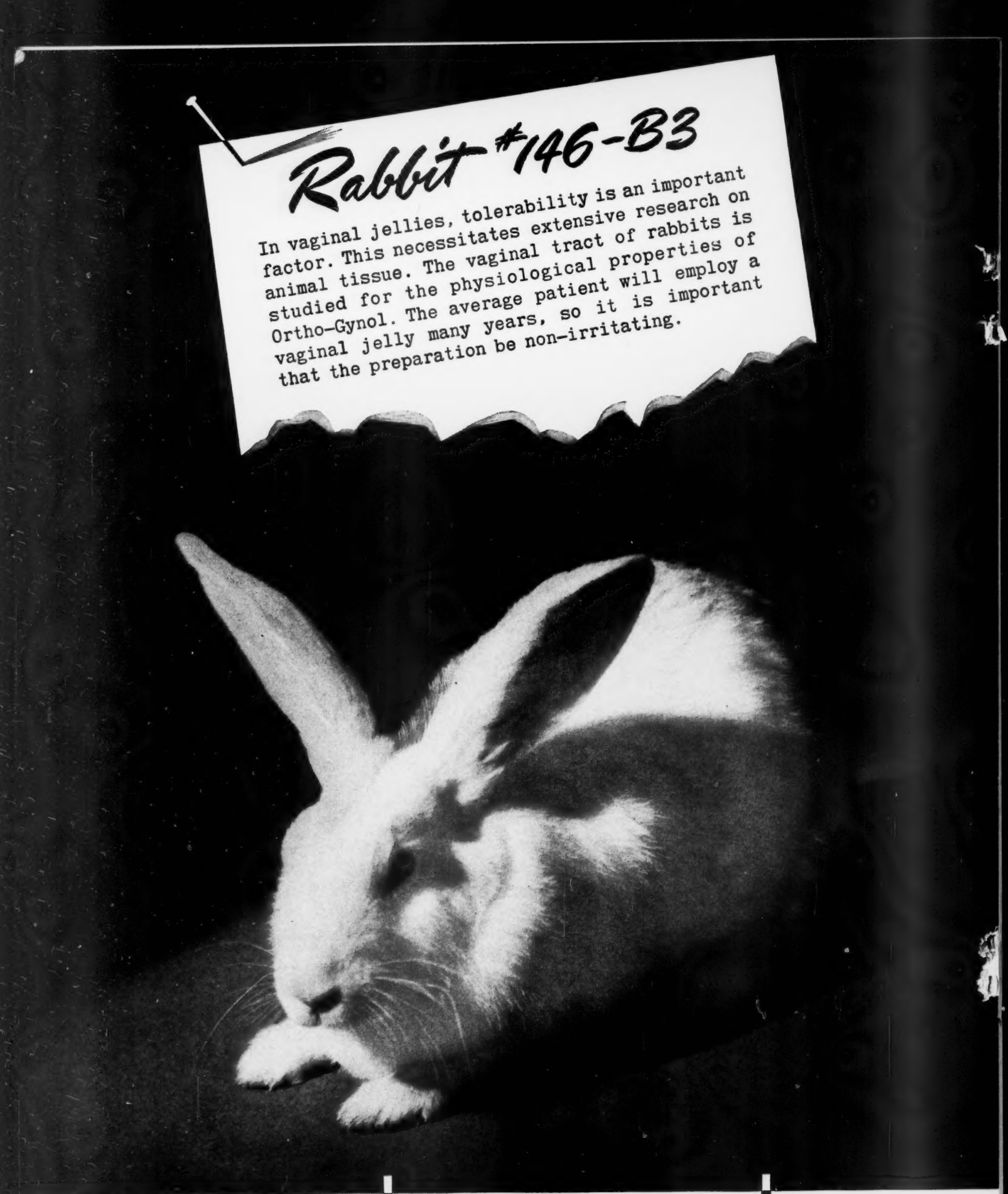
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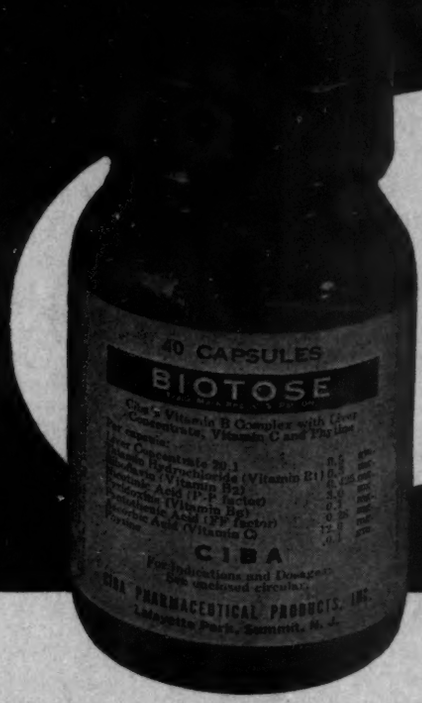


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